

**Alleviation of Conceptual Difficulties in Grade 12  
Mechanics by Addressing the Challenges Emanating  
from Alternative Conceptions**

***STEPHAN PARAFFIN MCHUNU***

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**ALLEVIATION OF CONCEPTUAL  
DIFFICULTIES IN GRADE 12 MECHANICS BY  
ADDRESSING THE CHALLENGES  
EMANATING FROM ALTERNATIVE  
CONCEPTIONS**

**BY**

**STEPHAN PARAFFIN MCHUNU**

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**UNIVERSITY OF ZULULAND  
KWADLANGEZWA**

**PROMOTER: Prof. S.N. Imenda**

**Submitted: January 2012**

**SIGNATURE: \_\_\_\_\_**

UNIVERSITY OF ZULULAND  
FACULTY OF EDUCATION

**DECLARATION FORM**

I Stephan Paraffin Mchunu of 2 Milky Way, Carsdale Suburb, Empangeni, sincerely and solemnly declare that the copy of the thesis submitted by me in January 2012 is original. It is in no way the work of someone else. The product is the result of my efforts through the professional guidance of the recognized supervisor whose names and signature appear below:

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**PROMOTER'S NAME:** \_\_\_\_\_

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## **DEDICATION**

This thesis is dedicated to:

My wife, Zodwa Magaret Mchunu, my son, Siyethaba Dalitso Mchunu and my daughter, Sibusisiwe Nokubonga Mchunu, who have been my source of joy and inspiration.

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## **ACRONYMS AND ABBREVIATION USED IN THIS STUDY**

OBE:	Outcomes-Based education
FET:	Further Education and Training
GET:	General Education and Training
IKS:	Indigenous Knowledge System
NCS:	National Curriculum Statement
DoE:	Department of Education
CASS:	Continuous Assessment
NQF:	National Qualification Framework
AS:	Assessment Standard
LO:	Learning Outcome
CO:	Critical Outcome
DO:	Developmental Outcome
SEM:	Superintendent of Education Management
NGO:	Non-Governmental Organization
SAG:	Subject Assessment Guidelines
LPG:	Learning Programme Guidelines
CPTD:	Continuing Professional Teacher Development
OBA:	Outcomes-Based Assessment
PCK:	Pedagogical Content Knowledge
POE:	Predict Observe and Explain
BMT:	Basic Mechanics Test
NSC:	National Senior Certificate

WBL :	Web-Based Learning
WBI:	Web-Based Instruction
WBE:	Web-Based Education
WWW:	World Wide Web
TBM:	Test in Basic Mechanics
CD:	Conceptual Difficulty and/or Compact Disc
AC:	Alternative Conceptions
SAQA:	South African Qualifications Authority
K:	Kinetic Energy
U:	Gravitational Potential Energy
PE:	Potential Energy
KE:	Kinetic Energy
KZN:	KwaZulu Natal
ANGS	Average Normalised Gain Score(s)
AT	Activity Theory



## **ABSTRACT**

This study sought to determine the conceptual difficulties experienced by grade 12 physical science learners with regard to mechanics. It also sought to identify the most prevalent alternative conceptions among grade 12 physical science learners in the area of mechanics, and develop interventions to alleviate the identified conceptual difficulties and alternative conceptions. In this regard, the study compared the effectiveness of a traditional lecture, outcomes-based education (OBE) and blended instructional approaches in alleviating or overcoming the identified conceptual difficulties and alternative conceptions concerning mechanics. The aspects of Mechanics dealt with in this study were: *work and energy, motion on the inclined surfaces, projectile motion, force concept, static objects and Newton's Third Law of Motion.*

In addressing the above research problem, the study developed and presented a theoretical and conceptual framework derived from the review of relevant literature, in line with the research questions of the study. The conceptual framework developed was based on the constructivist views of learning.

A total of one hundred and forty (140) grade 12 physical science learners from Empangeni Education District were involved in this study. The study followed the quasi-experimental non-equivalent comparison-group research design. Though quantitative in design, the study also used qualitative research methods. Thus, both quantitative and qualitative data were collected. From the quantitative data, the findings showed highly statistically significant gains between pre- and post-test scores of OBE and blended approaches in particular. The average normalised gain score concept was also used to determine the most effective instructional approach. Convenience sampling was used to select participating schools. A Test in Basic Mechanics (TBM) was designed to assess the learners' understanding of the most basic concepts in mechanics.

The TBM was administered both as a pre- and post-test to the three groups (traditional, OBE and blended groups) to determine the level of experience, knowledge, pre-existing alternative conceptions, level of understanding of basic concepts and principles on mechanics topics identified at the start of the investigation. As a pre-test, the TBM was also used to identify the specific conceptual difficulties and alternative conceptions in mechanics.

The identification of the conceptual difficulties and alternative conceptions after the pre-test was followed by three instructional interventions (the traditional, OBE and the blended approach). The three interventions addressed the same mechanics topics mentioned above. These interventions were then followed by post-tests to ascertain the effectiveness of the interventions in addressing the identified conceptual difficulties and alternative conceptions, as well as any conceptual difficulties and alternative conceptions which were resistant to change even after the interventions.

The results revealed that the learners experienced conceptual difficulties with regard to (a) resolving the components of the weight; (b) work concept; (c) work-energy theorem application; (d) kinetic energy concept; and (e) principle of conservation of mechanical energy application. Regarding the most prevalent alternative conceptions in mechanics, learners held eight alternative conceptions related to kinematical and dynamical concepts. Alternative conceptions held by the learners in mechanics concerned the following: (a) the acceleration and velocity of projectile motion; (b) weight/mass of an object as related to Newton's Third Law of motion; (c) force concept; (d) objects in motion; (e) static objects; (f) Newton's Third Law of motion; (g) acceleration of projectiles; and (h) active force.

The average normalised gains for the traditional, OBE and blended instructional approaches were  $(g) = 0,20$ ;  $(g) = 0,30$ ; and  $(g) = 0,60$ , respectively. This confirmed the statistical analysis computed using One Way Analysis of Variance (ANOVA), that the blended instructional approach was the most effective

instructional approach in alleviating the conceptual difficulties and alternative conceptions in mechanics. Qualitative data showed that most of the pre-existing conceptual difficulties and alternative conceptions appeared to have been alleviated, although not completely overcome by the interventions. There were statistically significant differences that were found among the traditional, OBE and blended instructional interventions. It is therefore noted that the blended instructional approach to teaching and learning can have a significant contribution to overcoming conceptual difficulties and alternative conceptions in mechanics, and the improvement of efficiency of learning. The study concluded that conceptual difficulties and alternative conceptions in mechanics could best be alleviated using the blended approach to teaching and learning. A number of recommendations were also made. Some alternative conceptions were resistant to change in the face of the traditional lecture based teaching. This meant that a more powerful teaching technique had to be devised. Thus, physical science educators should be encouraged to use the blended approach to teaching and learning in order to accommodate all learners in a class. Blended teaching and learning is mixing of different teaching and learning environments – mainly manifested in combining face-to-face instruction with the computer mediated-instruction. In one class of learners there are different learner characteristics. Learners learn in different ways like learning through lecture (telling), discussion, problem solving, practical work, discovering, experimenting, using pictures and diagrams, videos and demonstrations.

## TABLE OF CONTENTS

<u>ITEM</u>	<u>PAGE</u>
TITLE PAGE	(I)
DECLARATION FORM	(II)
DEDICATION	(III)
ACKNOWLEDGEMENT	(IV)
ACRONYMS AND ABBREVIATIONS	(VI)
ABSTRACT	(VIII)
TABLE OF CONTENTS	(XI)
LIST OF TABLES	(XIX)
LIST OF FIGURES	(XXII)
 <b>CHAPTER ONE: INTRODUCTION</b>	 <b>1</b>
1.1 OVERVIEW	1
1.2 BACKGROUND	1
1.3 THE STATEMENT OF THE PROBLEM	5
1.4 THE AIM OF THE STUDY	17
1.4.1 Research Questions	18
1.4.2 Research Objectives	18
1.4.3 Statistical Hypotheses	19
1.5 THE SIGNIFICANCE OF THE STUDY	20
1.6 METHOD OF STUDY	21
1.6.1 Research Design	22
1.6.2 Literature Study	24
1.6.3 Empirical Study	24
1.6.4 Research Instruments	25
1.6.5 Data Analysis and Interpretation	26
1.7 DEMARCATION OF THE FIELD OF STUDY	26
1.8 LIMITATIONS OF THE STUDY	26

1.9	DEFINITION OF TERMS	27
1.9.1	Instructional Method	27
1.9.2	Blended Teaching and Learning	27
1.9.3	Traditional Teaching Method	27
1.9.4	Outcomes-Based Education	27
1.9.5	Physical Sciences	28
1.9.6	Curriculum	29
1.9.7	Alternative Conceptions	30
1.9.8	Constructivism	30
1.9.9	Mechanics	30
1.10	THE STRUCTURE OF THE DISSERTATION	31
1.11	CONCLUSION	31
	<b>CHAPTER TWO: LITERATURE REVIEW</b>	<b>32</b>
2.1	OVERVIEW	32
2.2	CONCEPTUAL DIFFICULTIES IN MECHANICS	32
2.2.1	Conceptual Difficulties about Work and Energy	35
2.2.2	Conceptual Difficulties about Projectile Motion	43
2.3	ALTERNATIVE CONCEPTIONS IN MECHANICS	46
2.3.1	Origin of Alternative Conceptions	47
2.3.2	Overcoming Alternative Conceptions	48
2.3.3	Alternative Conceptions about Force and Newton's Laws	52
2.4	LEARNING THEORIES	56
2.4.1	Jean Piaget (Theory of Cognitive Development)	59
2.4.2	David Ausubel	61
2.4.3	Jerome Bruner	63
2.4.4	Robert Gagne`	65
2.4.5	Joseph Novak	67
2.4.6	Ernst von Glasersfeld	68
2.4.7	John Dewey	70
2.4.8	Lev Vygotsky	72
2.4.9	Behaviourist Theory of Learning	74
2.4.10	Constructivist Theory of Learning	78

2.4.10.1	Constructivist Theory and Science Education	80
2.4.10.2	The Constructivist Classroom	83
2.4.10.3	The Constructivist Teacher	85
2.4.11	Connectivism	89
2.4.12	Summary of the Learning Theory	92
2.5	ACTIVITY THEORY	93
2.5.1	Description of the Activity Theory	94
2.5.2	Review of Studies that have used Activity Theory	97
2.5.3	Activity Theory as Applied to this Study	103
2.5.3.1	AT as Applied to the Traditional Intervention Group	104
2.5.3.2	AT as Applied to the OBE Intervention Group	105
2.5.3.3	AT as Applied to the Blended Intervention Group	107
2.6	CURRICULUM DEVELOPMENT AND IMPLEMENTATION	108
2.6.1	Curriculum Design Models and Planning of Lessons	113
2.6.2	Implementation of Instructional Planning	118
2.6.3	General Curriculum Functions	120
2.6.4	Designing the NCS Learning Programme	121
2.7	THE TRADITIONAL, OBE AND BLENDED APPROACHES TO TEACHING AND LEARNING	123
2.7.1	The Traditional Approach to Teaching and Learning	124
2.7.1.1	The Relationship between the Traditional Approach and NCS	126
2.7.1.2	Instructional Approach in Traditional Education	127
2.7.1.3	Outcomes in Traditional Approach in Terms of AT	129
2.7.1.4	Assessment in Traditional Education	130
2.7.1.5	Continuous Assessment in Traditional Education	132

2.7.2	The OBE Approach to Teaching and Learning	134
2.7.2.1	The Relationship between the OBE and NCS	141
2.7.2.2	Instructional Approach in OBE	145
2.7.2.3	Outcomes	147
2.7.2.3.1	Types of Outcomes	147
2.7.2.3.2	Outcomes-based Assessment	152
2.7.2.3.3	Continuous Assessment in OBE	160
2.7.3	The Blended Approach to Teaching and Learning	163
2.7.3.1	The Relationship between Blended and NCS	168
2.7.3.2	Instructional Approaches in Blended Teaching and Learning	168
2.7.3.3	Outcomes in Blended Approach in Terms of AT	169
2.7.3.4	Assessment in Blended Teaching and Learning	171
2.7.3.5	Continuous Assessment in Blended Teaching and Learning	174
2.7.3.6	Computer-mediated Learning	176
2.7.3.7	WBL Learning Environment	177
2.7.3.8	The Role of WBL Learning Facilitator	178
2.7.3.9	Constructivism in the Electronic Learning Environment	179
2.7.3.10	Implementation of the Blended Approach	180
2.7.3.11	Categories of Learner Experiences	182
2.7.3.12	Importance of Blended Teaching	188
2.7.3.13	Blended Learning Models	188
2.8	CONCLUSION	190

<b>CHAPTER THREE: RESEARCH METHODS</b>	<b>192</b>
3.1 INTRODUCTION	192
3.2 THE RESEARCH QUESTIONS RE-STATED	192
3.3 THE STATISTICAL HYPOTHESES	193
3.4 RESEARCH DESIGN	193
3.5 TARGET AND ACCESSIBLE POPULATION	202
3.6 THE RESEARCH SAMPLE AND SAMPLING PROCEDURES	203
3.7 MIXED METHODS RESEARCH AND TRIANGULATION	204
3.8 THE RESEARCH INSTRUMENT	207
3.8.1 The Test in Basic Mechanics (TBM)	207
3.8.2 Open-ended Questions	211
3.8.3 Closed Questions	211
3.8.4 Validity and Reliability of Research Instrument	212
3.8.4.1 Validity of the Above-mentioned Instruments	213
3.8.4.2 Reliability of Instruments Used in this Research Study	216
3.9 INSTRUCTIONAL INTERVENTIONS	220
3.9.1 Traditional Approach Intervention	220
3.9.2 OBE Approach Intervention	222
3.9.3 Blended Approach Intervention	225
3.10 PILOT STUDY	230
3.11 DATA COLLECTION PROCEDURES	237
3.12 DATA ANALYSIS TECHNIQUE AND PROCEDURES	237
3.12.1 Quantitative Analysis	238
3.12.2 Qualitative Analysis	239
3.12.3 Statistical Analysis	240
3.13 ETHICAL CONSIDERATIONS	242
3.14 CONCLUSION	246



<b>CHAPTER FOUR: RESULTS AND DISCUSSION</b>	<b>248</b>
4.1 OVERVIEW	248
4.2 BIOGRAPHICAL PROFILE OF RESPONDENTS	249
4.2.1 Gender Distribution of Respondents	249
4.2.2 Age Distribution of Respondents	250
4.2.3 Home and First Additional Language of Learner Respondents	250
4.2.4 Preferences of Instructional Strategies	251
4.2.5 Learners' Views about OBE	252
4.2.6 Assessment Methods Preferences	257
4.2.7 Familiar Topics in Mechanics	258
4.3 MOST PREVALENT CONCEPTUAL DIFFICULTIES	258
4.3.1 Quantitative and Qualitative Analysis of Pre-Test	259
4.3.2 Categories for Most Prevalent Conceptual Difficulties in Mechanics	283
4.3.2.1 CD 1: Motion on Inclined Planes and Components of Vectors	287
4.3.2.2 CD 2: Work Concept	288
4.3.2.3 CD 3: Work-Energy Theorem	290
4.3.2.4 CD 4: Kinetic Energy	292
4.3.2.5 CD 5: Principle of Conservation of Mechanical Energy	293
4.4 MOST PREVALENT ALTERNATIVE CONCEPTIONS	295
4.4.1 Quantitative and Qualitative Analysis of Pre-Test	295
4.4.2 Categories of Most Prevalent Alternative Conceptions in Mechanics	312
4.4.2.1 AC 1: The Velocity and Acceleration of Projectiles	315
4.4.2.2 AC 2: Weight/Mass of an Object	317
4.4.2.3 AC 3: Force Concept	318
4.4.2.4 AC 4: Objects in Motion	319
4.4.2.5 AC 5: Static Objects	320
4.4.2.6 AC 6: Newton's Third Law of Motion	322
4.4.2.7 AC 7: Acceleration of Projectiles	323
4.4.2.8 AC 8: Active Force	324
4.5 INTERVENTIONS DEVELOPED AND IMPLEMENTED	325
4.5.1 Traditional Intervention	325

4.5.2	OBE Intervention	326
4.5.3	Blended Intervention	327
4.5.4	Quantitative and Qualitative Analysis of the Post-test for Conceptual Difficulties in mechanics	327
4.5.5	Alleviation of Conceptual Difficulties	343
4.5.6	Quantitative and Qualitative Analysis of the Post-test for Conceptual Difficulties in mechanics	347
4.5.7	Alleviation of Alternative Conceptions	357
4.6	EFFECTIVENESS OF INTERVENTIONS	360
4.6.1	The Analysis of Variance	361
4.6.2	The Average Normalised Gain Score Concept	376
4.7	DISCUSSION OF FINDINGS	378
4.7.1	Assessment Preferences of Learners	381
4.7.2	Teaching Strategies Preferences of Learners	382
4.7.3	Learners' Responses on OBE	383
4.7.4	Conceptual Difficulties in Mechanics	387
4.7.5	Alternative Conceptions in Mechanics	393
4.7.6	The Effectiveness of the Interventions	401
4.8	CONCLUSION	405
<b>CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS</b>		<b>407</b>
5.1	SUMMARY	407
5.1.1	Aim	407
5.1.2	The Conceptual Framework	410
5.1.3	Interventions	410
5.1.4	The Methodology	412
5.1.5	Major Findings	413
5.2	CONCLUSION	416
5.3	RECOMMENDATIONS	418
5.4	THE IMPORTANCE OF THIS STUDY	420
5.5	SPECIAL ACKNOWLEDGEMENT	424

<b>REFERENCES</b>	<b>425</b>
APPENDIX A: Test in Basic Mechanics	492
APPENDIX B: Traditional Intervention Curriculum Development	512
APPENDIX C: OBE Intervention Curriculum Development	519
APPENDIX D: Blended Intervention Curriculum Development	522
APPENDIX E: BMT Scores	526
APPENDIX E 1: BMT (Pre-Test) Scores for All Four Groups	526
APPENDIX E 2: Traditional Group Pre- and post-Test Scores	527
APPENDIX E 3: OBE Group Pre- and post-Test Scores	528
APPENDIX E 4: Blended Group Pre- and post-Test Scores	529
APPENDIX E 5: Comparison Group Pre- and post-Test Scores	530
APPENDIX E 6: BMT (Post-Test) Scores	531
APPENDIX E 7: Traditional versus OBE Group Scores	532
APPENDIX E 8: Traditional versus Blended Group Scores	533
APPENDIX E 9: OBE versus Blended Group Scores	534
APPENDIX F: Correspondence	535
APPENDIX F 1: Letter to Empangeni Education District Manager	536
APPENDIX F 2: Letter to Lower Umfolozi Circuit Manager	537
APPENDIX F 3: Letter to Richards Bay Ward Manager	538
APPENDIX F 4: Letter to School Principals	539

<b><u>ITEM</u></b>	<b><u>LIST OF TABLES</u></b>	<b><u>PAGE</u></b>
Table 1.1	Empangeni District Physical Science Generic rating scale and learner achievement level for the NCS, 2008	12
Table 1.2	Empangeni District Physical Science Generic rating scale and learner achievement level for the NCS, 2009	14
Table 1.3	Empangeni District Physical Science Generic rating scale and learner achievement level for the NCS, 2010	16
Table 2.1	The Examples of Action and Reaction Forces	54
Table 2.2	The summary of the major characteristics of the learning Theories	92
Table 2.3	A Glimpse of Students Learning Styles	182
Table 2.4	Key Features of the Blended Lesson Models	189
Table 4.1	Gender Distribution of Respondents	249
Table 4.2	Age Distribution of Respondents	250
Table 4.3	Instructional Strategies Preferences Distribution of Respondents	251
Table 4.4	Assessment Method Preferences of Respondents	257
Table 4.5	Most Prevalent Conceptual Difficulties in Mechanics	284
Table 4.6	Most Prevalent Alternative Conceptions in Mechanics	313
Table 4.7	Most Prevalent Conceptual Difficulties in Mechanics	343
Table 4.8	Most Prevalent Alternative Conceptions in Mechanics	358
Table 4.9	Comparisons of the Means of the Traditional, OBE Blended and Comparison Group on the Pre-Test	362
Table 4.10	Summary of the Statistical Differences among the Four Groups on the TBM at the onset of the study	362

Table 4.11	The z-test Summary of the Difference in Pre- and Post-test Scores of the Learners Exposed to the traditional Approach	364
Table 4.12	Analysis of Variance (ANOVA) between Pre-and Post-test Scores of Learners Exposed to the Traditional Approach	364
Table 4.13	The z-test Summary of the Difference in Pre- and Post-test Scores of the Learners Exposed to the OBE Approach	365
Table 4.14	Analysis of Variance (ANOVA) between Pre-and Post-test Scores of Learners Exposed to the OBE Approach	366
Table 4.15	The z-test Summary of the Difference in Pre- and Post-test Scores of the Learners Exposed to the Blended Approach	367
Table 4.16	Analysis of Variance (ANOVA) between Pre-and Post-test Scores of Learners Exposed to the Blended Approach	368
Table 4.17	The z-test Summary of the Difference in Pre- and Post-test Scores for the Comparison group	368
Table 4.18	Analysis of Variance (ANOVA) between Pre-and Post-test Scores for the Comparison Group	369
Table 4.19	Comparison of the Traditional, OBE and Blended groups on the Post-test	370
Table 4.20	Analysis of Variance (ANOVA) for the Three Interventions Groups	371
Table 4.21	Comparison of the Traditional and OBE Groups on the Post-test	372
Table 4.22	Analysis of Variance (ANOVA) between two Teaching Approaches (Traditional and OBE Interventions)	373

Table 4.23	Comparison of the Traditional and Blended Groups on the Post-test	373
Table 4.24	Analysis of Variance (ANOVA) between two Teaching Approaches (Traditional and Blended Interventions)	374
Table 4.25	Comparison of the OBE and Blended Groups on the Post-test	375
Table 4.26	Analysis of Variance (ANOVA) between two Teaching Approaches (OBE and Blended Interventions)	375
Table 4.27	Comparisons of all the Groups Based on the AGS concept	377
Table 5.1	Blended Teaching and Learning Model	422

<b><u>ITEM</u></b>	<b><u>LIST OF FIGURES</u></b>	<b><u>PAGE</u></b>
Figure 1.1	Empangeni education District Physical Science Pass Rate 2008	11
Figure 2.1	Activity Theory's Model	95
Figure 2.2	Activity System for Three Intervention Groups	104
Figure 2.3	Taba's Linear "Objectives" model	114
Figure 2.4	An Example of an Interactive Model	116
Figure 2.5	An Example of a Cyclical Model	117
Figure 2.6	Traditional Teaching Model Followed in this Study	133
Figure 2.7	OBE Teaching Model Followed in this Study	135
Figure 2.8	Hierarchical Native of Activities, Actions and Operations	139
Figure 2.9	Broad Conceptualisation of Blended Learning	164
Figure 2.10	Blended Teaching Model Followed in this Study	175
Figure 3.1	Research Process Diagram	247
Figure 4.1	Number of learners who selected the intended response from the four groups (Pre-test Question 1)	260
Figure 4.2	Number of learners who selected the intended response from the four groups (Pre-test Question 2)	262
Figure 4.3	Number of learners who selected the intended response from the four groups (Pre-test Question 3)	264
Figure 4.4	Number of learners who selected the intended response from the four groups (Pre-test Question 4)	265
Figure 4.5	Number of learners who selected the intended response from the four groups (Pre-test Question 5)	267
Figure 4.6	Number of learners who selected the intended response from the four groups (Pre-test Question 6)	269

Figure 4.7	Number of learners who selected the intended response from the four groups (Pre-test Question 7)	271
Figure 4.8	Number of learners who selected the intended response from the four groups (Pre-test Question 8)	272
Figure 4.9	Number of learners who selected the intended response from the four groups (Pre-test Question 9)	274
Figure 4.10	Number of learners who selected the intended response from the four groups (Pre-test Question 10)	275
Figure 4.11	Number of learners who selected the intended response from the four groups (Pre-test Question 11)	277
Figure 4.12	Number of learners who selected the intended response from the four groups (Pre-test Question 12)	278
Figure 4.13	Number of learners who selected the intended response from the four groups (Pre-test Question 13)	280
Figure 4.14	Number of learners who selected the intended response from the four groups (Pre-test Question 14)	281
Figure 4.15	Number of learners who selected the intended response from the four groups (Pre-test Question 15)	282
Figure 4.16	Most Prevalent Conceptual Difficulties before Interventions	286
Figure 4.17	Number of learners who selected the intended response from the four groups (Pre-test Question 16)	296
Figure 4.18	Number of learners who selected the intended response from the four groups (Pre-test Question 17)	297
Figure 4.19	Number of learners who selected the intended response from the four groups (Pre-test Question 18)	299
Figure 4.20	Number of learners who selected the intended response from the four groups (Pre-test Question 19)	300
Figure 4.21	Number of learners who selected the intended response from the four groups (Pre-test Question 20)	302



Figure 4.22	Number of learners who selected the intended response from the four groups (Pre-test Question 21)	304
Figure 4.23	Number of learners who selected the intended response from the four groups (Pre-test Question 22)	305
Figure 4.24	Number of learners who selected the intended response from the four groups (Pre-test Question 23)	307
Figure 4.25	Number of learners who selected the intended response from the four groups (Pre-test Question 24)	308
Figure 4.26	Number of learners who selected the intended response from the four groups (Pre-test Question 25)	310
Figure 4.27	Most Prevalent Alternative Conceptions before Interventions	314
Figure 4.28	Number of learners who selected the intended response from the four groups (Post-test Question 1)	328
Figure 4.29	Number of learners who selected the intended response from the four groups (Post-test Question 2)	329
Figure 4.30	Number of learners who selected the intended response from the four groups (Post-test Question 3)	330
Figure 4.31	Number of learners who selected the intended response from the four groups (Post-test Question 4)	331
Figure 4.32	Number of learners who selected the intended response from the four groups (Post-test Question 5)	332
Figure 4.33	Number of learners who selected the intended response from the four groups (Post-test Question 6)	333
Figure 4.34	Number of learners who selected the intended response from the four groups (Post-test Question 7)	334
Figure 4.35	Number of learners who selected the intended response from the four groups (Post-test Question 8)	335
Figure 4.36	Number of learners who selected the intended response from the four groups (Post-test Question 9)	336
Figure 4.37	Number of learners who selected the intended response from the four groups (Post-test Question 10)	337

Figure 4.38	Number of learners who selected the intended response from the four groups (Post-test Question 11)	338
Figure 4.39	Number of learners who selected the intended response from the four groups (Post-test Question 12)	339
Figure 4.40	Number of learners who selected the intended response from the four groups (Post-test Question 13)	340
Figure 4.41	Number of learners who selected the intended response from the four groups (Post-test Question 14)	341
Figure 4.42	Number of learners who selected the intended response from the four groups (Post-test Question 15)	342
Figure 4.43	Most Prevalent Conceptual Difficulties after Interventions	346
Figure 4.44	Number of learners who selected the intended response from the four groups (Post-test Question 16)	347
Figure 4.45	Number of learners who selected the intended response from the four groups (Post-test Question 17)	348
Figure 4.46	Number of learners who selected the intended response from the four groups (Post-test Question 18)	349
Figure 4.47	Number of learners who selected the intended response from the four groups (Post-test Question 19)	350
Figure 4.48	Number of learners who selected the intended response from the four groups (Post-test Question 20)	351
Figure 4.49	Number of learners who selected the intended response from the four groups (Post-test Question 21)	352
Figure 4.50	Number of learners who selected the intended response from the four groups (Post-test Question 22)	353
Figure 4.51	Number of learners who selected the intended response from the four groups (Post-test Question 23)	354
Figure 4.52	Number of learners who selected the intended response from the four groups (Post-test Question 24)	355
Figure 4.53	Number of learners who selected the intended response from the four groups (Post-test Question 25)	356



# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 OVERVIEW**

This chapter presents the background to the problem, the statement of the problem and the aims of the study. It also presents research questions, the significance of the study, brief statement of the methodology, demarcation of the field of study, limitations of the study, definition of terms as well as the structure of the thesis.

This study combined two sciences, the natural and behavioural sciences: natural sciences as the study dealt with mechanics in physics and behavioural sciences as it dealt with education. The combination of the two sciences made it a Science Education study.

### **1.2 BACKGROUND TO THE PROBLEM**

Since the introduction of the National Curriculum Statement (NCS), physical science educators experienced many challenges with regard to the implementation of the new curriculum. The new curriculum introduced many changes to the subject, such as new content knowledge areas and core concepts, learning outcomes (LOs), assessment standards (ASs), and the inclusion of practical investigations as well as research projects as compulsory components of the assessment programme for physical science in Grade 12 which is in the Further Education and Training (FET) band.

In most cases, change is about people – their ideas, their fears, and the capacity to imagine and work together for a different future. The changes brought about

by the new curriculum called for all school and education stakeholders to work together, and as close to each other as possible. The teacher-parent-learner relationship had therefore to be strengthened. There was no parent orientation or literacy towards the new curriculum before it was implemented. Furthermore, there was not sufficient educator professional development on the new content knowledge areas and pedagogical content knowledge (PCK). As Jita and Mokhele (2008:254) observe “many schools in South Africa and elsewhere struggle to offer high quality instruction, especially in the Sciences and Mathematics”. Curriculum resources and facilities were also a serious challenge in the implementation of the new curriculum. Jita and Mokhele (2008:258) aver that “it is not only the presence or absence of the teachers that makes a difference, but the competence of teachers in content, pedagogy and assessment of their subject area”. Jita and Mokhele (2008:254) also posit that “education leaders across the globe have been searching for promising solutions to this problem, which has often been defined as ‘capacity problem’”.

On its part, the Department of Education (1998:50, 52-55) states that

the issue of teacher development cannot be left with the Department of Education alone as a problem to solve. Educators are also expected to solve the problems related to professional development in content knowledge and in pedagogy as life-long learners.

According to the Department of Education (DoE) (1998:50; 52-55) one of the seven educator roles, namely,

Scholar, researcher and life long learner and its applied competences, specifies that educators should also research their own teaching as reflective practitioners, relating theory to practice and seeking to accomplish personal, academic, occupational and professional growth to improve their practice.

In general, educators can learn a lot from their own experiences and from their colleagues. Literature sees “reflection as a social exercise and claims that

educators' professional growth would be suppressed without a social group setting of collegial and collaborative participation" (Rossouw, 2009:2). In this regard, Rossouw (2009:1) also argues that "educators need to continually reflect on their own teaching practice, take responsibility for their actions and make thoughtful decisions and changes based on their own distinctive experiences in the classroom". As such, educators are mostly expected to share ideas on their experiences regarding challenges they encounter as they implement the curriculum (Rossouw, 2009). Rossouw (2009:1) further maintains that

the ability, to interpret classroom activity critically, to translate knowledge, wisdom and experience into a form of communication that is compelling and interesting, to identify and solve problems regarding teaching practice and to make thoughtful or reflective instructional and classroom management decisions that are conducive to learning, is a characteristic of expert educators.

Educators need to have or demonstrate all the qualities mentioned above, as Rossouw (2009:3) explains:

Teaching today places educators in an environment where complex interpersonal relationships require constant mediation in order for parties to reach working agreements while balancing a multiplicity of tasks and roles. Moreover, this activity takes place in a social and political context within a culturally diverse society facing economic constraints. For example, South African educators are increasingly facing changes in the complex social context in which they work and for which they may not have been trained.

Furthermore, it is noted that a review of recent trends in the teaching and learning of mathematics and science in particular, within the context of lifelong learning, acknowledges that school science and mathematics education plays an important role in societal development (Department of Education, 2002).

According to the Department of Education (2002:2), this role entails, *inter alia*, the following:

- Science and mathematics education is the base upon which expertise in technological development and deployment takes place.
- School science and mathematics enhance the scientific literacy and technological fluency of citizens so that they can participate more fully in decisions that affect their lives.
- The need for a new emphasis on science education is recognised worldwide.
- South Africa now has a comprehensive science and technology policy, although there is a concern that it lacks specific consideration concerning science and mathematics education.

There are six knowledge areas in physical sciences. This study is only limited to mechanics knowledge area. For this study, the researcher chose mechanics as one of the most challenging sections in the physical science curriculum for Grade 12. Accordingly, the study focused on conceptual difficulties and alternative conceptions in mechanics in the Grade 12 physical science curriculum. There are only a few fundamental laws, principles and rules learners need to understand in Grade 12 mechanics (Bueche, 1986). These laws, principles and rules are used to deduce how nature behaves in a multitude of situations. The main purpose of mechanics is to teach learners the fundamental laws and principles of physics and to give them experience in reasoning out how these laws and principles apply to the world (Bueche, 1986). Bueche (1986) further states that physics, in particular, involves learners' intellect to the fullest. Learners are required to think and reason carefully about the puzzling problems posed by nature. Furthermore, Bueche (1986) also posits that doing physics is basically solving mathematical and conceptual problems. To solve problems in mechanics, learners need to have a clear understanding of the basic principles of mechanics. However, there are conceptual blocks and alternative conceptions in

mechanics. This study, therefore, sought to investigate whether specific instructional approaches could help alleviate or overcome these conceptual difficulties and alternative conceptions.

Coetzee (2008) states that the most common origin of alternative conceptions could be any previous life experience or observation by the learner, not necessarily arising out of training. Coetzee (2008) further posits that the most important point is that alternative conceptions, once formed, influence learners' observations and the sense they make of further learning. In the same vein, Driver (1983, as cited by Coetzee, 2008:76) avers that "these conceptions are resistant to change, thus making a considerable number of learners hold on to certain intuitive notions despite the science teaching they receive in school".

Furthermore, Coetzee (2008) maintains that learners come to science lessons particularly, with some already strongly held ideas, which may differ from the theories the educator may wish to develop. In support of Coetzee's statement, Marais (2009) states that an individual's previous experience and environmental background influence how he/she interprets knowledge and retain it. Many of the conceptual difficulties learners encounter in mechanics involve mathematical reasoning skills. Low levels of such skills among learners create the belief that mechanics is difficult to learn.

### **1.3 STATEMENT OF THE PROBLEM**

Physical science educators in high schools have had challenges in implementing the NCS (Mchunu, 2009). Challenges experienced by these educators, among other things, concerned the following: inadequate educator professional development, difficulty in dealing with instructional strategies, inadequate enabling resources and low level of parental involvement in the education of their children. The findings of a previous study (Mchunu, 2009) revealed that about 69% of physical science educators, teaching in high schools had never



participated in professional meetings or conferences that focused on teaching. However, a very low percentage (6.25%) of educators had attended such events many times which assisted in their professional development. Mchunu's (2009) also revealed the following professional developmental needs of physical science educators in high schools:

- Improvement in the understanding of Outcomes-Based Education (OBE) and the new curriculum;
- Development of physical science content knowledge;
- Workshops and short courses on OBE, focusing on the FET band;
- Development of pedagogical content knowledge e.g. obtaining ideas on how to teach content, deal with students' misconceptions, design learning programmes and design rubrics.

In the experience of the researcher, the following mechanics topics for Grades 10 – 12 physical science curricula, include concepts that present frequent stumbling blocks to problem solving, particularly with regard to the application of mechanics principles:

- Work and energy;
- Force, momentum and impulse;
- Weight and acceleration due to gravity;
- Kinematics graphs;
- Projectile motion; and
- Frames of reference.

Learners faced challenges in solving work and energy problems that involved friction when objects moved on a rough inclined surface. They also found it difficult to identify the components of the weight for bodies sliding on the inclined surface as well as expressing them in terms of the trigonometric ratios. According to the examiners' report for 2009 analysis of physical science performance in Grade 12, "mechanics principles and equations were poorly understood and applied" (Department of Education, 2009:1). They further reported that "the majority of candidates omitted  $\cos\theta$  in the work and energy

equation  $W = F\Delta X \cos\theta$  and as a result lost the marks”. Furthermore, the examiners also reported that “there was a lack of understanding of common assessment instructions such as ‘define’, ‘explain’, ‘state how the power output(s) compare’, etc” (Department of Education, 2009:2).

In the experience of the researcher with regard to force concepts, learners had conceptual difficulty in distinguishing between forces exerted by, or on, a body and hence they found it difficult to draw force diagrams and/or free body diagrams. There were also alternative conceptions with regard to Newton’s laws, particularly the application of the laws to problem solving. Another area of difficulty was when learners learned momentum and impulse. Learners found it difficult to identify key words or key concepts in a statement or question when they were solving problems involving momentum and impulse.

Regarding projectile motion and graphs of motion, learners were confused when they were required to draw the graphs and interpret them. The appropriate use of negative and positive signs for problems involving opposite directions was also a stumbling block to problem solving. Learners tended to associate the signs with the magnitude of the number as in mathematics, instead of associating them with particular directions. Learners also had confusion as to when to use the equations of motion. They also had a poor understanding of the frames of reference concept. In this regard, physical science educators need more pedagogical content knowledge training in mechanics. To alleviate some of the conceptual blockages, all schools should be adequately resourced, so that practical investigations and experiments become possible. The examiners also reported that “candidates had no exposure to investigation type questions” (Department of Education, 2009:4). An investigation in physics is an area that needs intensive application. Learners need greater practice at developing investigative questions, hypotheses, analyzing data and drawing conclusions so as to become competent in these skills.

Laugksch, Rakumako, Manyelo & Mabye (2005:273) observe that:

the South African government's National Curriculum Statement for grades 10 to 12 (Department of Education, 2003a) – in line with its earlier White Paper on Science and Technology (Department of Arts, Culture, Science and Technology, 1996) – makes it clear that adequate skills and knowledge of mathematics and physical / life sciences are believed to be a vital component of successful contemporary life and socio-economic development.

The NCS promotes learner empowerment and learner-centred learning environments. This calls for educators to be knowledgeable, skillful and to be masters of their subjects. Learners are expected to have the skill to interpret information and construct their own meanings by reflecting and making associations with prior knowledge to reach new understandings. Although learners are responsible for learning, educators need skills and knowledge so as to be good facilitators of the learning process. It is not only the subject matter that counts on the part of educators but also the way of facilitating knowledge to learners.

Laugksch, *et al* (2005:273) further revealed that “among the many factors that influence achievement in mathematics and the natural sciences, the role of teachers’ pedagogical knowledge and skills in their subject area is acknowledged to be a key factor”. In the same vein, it was noted that teachers’ craft knowledge – that is, knowledge and beliefs regarding pedagogy, students, subject matter and curriculum is mostly related to teacher effectiveness (Van Driel, Verloop & De Vos, 1998; Darling-Hammond, 2000; Hill, Rowan & Ball, 2005). Moreover, there is also overriding evidence that teacher quality in terms of teacher preparation and qualification strongly influence students’ level of achievement (Darling-Hammond, 2000; Darling-Hammond, Berry & Thoreson, 2001; Goldhaber & Brewer, 2000). However, it is widely recognised that, for historical reasons, the training of mathematics, physical science, and biology teachers... is

of variable, but largely inadequate, quality (Arnott, Kubeka, Rice & Hall, 1997; Mailula, 1995; Ngoepe, 1995).

The Head of the KZN Education Department, Dr Cassius Lubisi identified the subjects that presented the most difficulty for learners in KZN. In line with the national trends, they were accounting, physical science and economics. In particular, it was reported (The Mercury, 2008:2) that pupils had serious problems with physical science: from over 52000 pupils who wrote physical science, only about 48% passed in matric 2008 final examinations in KZN Province. According to the media, “the suspected reason for the poor pass rates was the changed content. It was also thought that examiners went a bit overboard and set some papers at university level” (The Mercury, 2008:2). This research sought to find out some of the reasons for the reported physical science failure rate in the FET band (grades 10-12) in rural schools.

The implication of the changes in the curriculum is that educators need to have an adequate understanding of all these changes, as well as the skills to carry out their various tasks successful if not, they could become barriers to the introduction, management, and the implementation of the NCS. Consequently, educator empowerment may be seen as the main strategy for providing educators with facilitating skills. As De Waal (2004:63) observes “teachers are falling behind due to insufficient training and development”. Jacobs, Gawe and Vakalisa (2002:107) pushed this point further as follows:

There is a widespread feeling that teachers have not been properly prepared for OBE. It would appear that the knowledge base, concept understanding and general capacity of many teachers were below par before the introduction of OBE. Despite this situation, the new system has been imposed on them without well-constructed in-service teacher training programmes to support the new initiative.

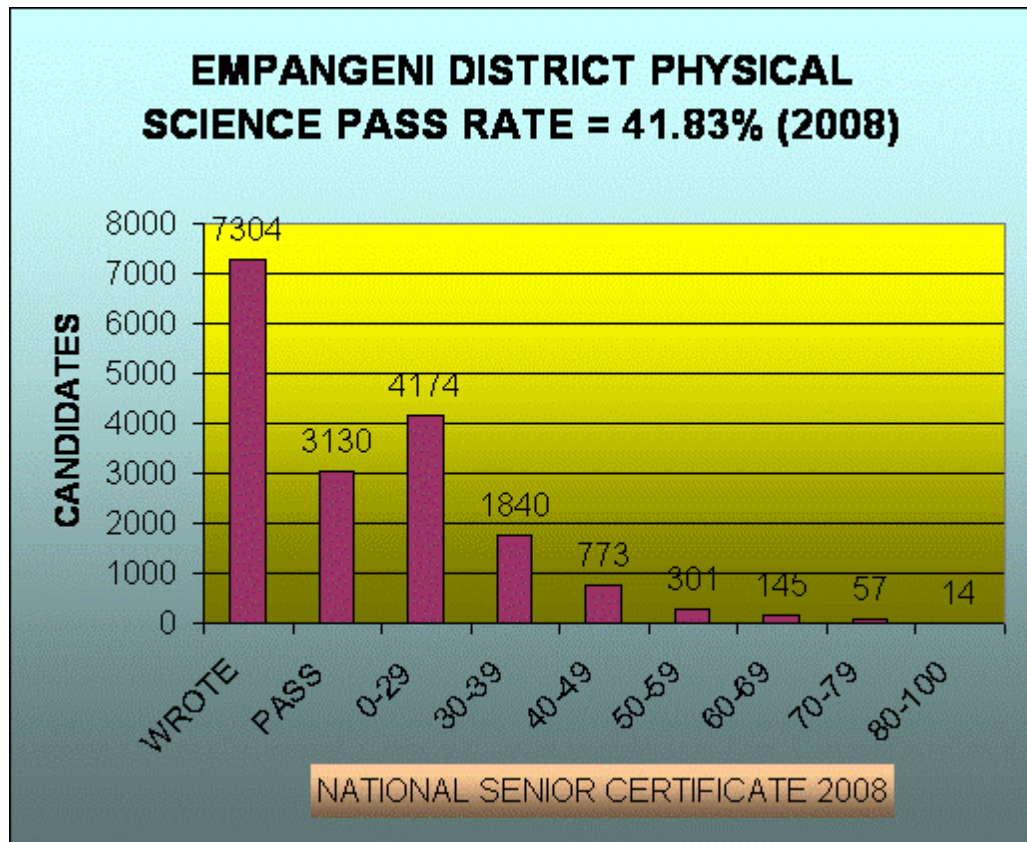
The new curriculum was introduced in the FET band (Grades 10 – 12) in 2006 when physical science educators were not made ready and prepared to meet its

demands. Physical science curriculum for Grade 10 – 12 has LOs and ASs that require proper understanding by educators as they implement the curriculum. LO 1 for example, is mostly about instilling practical investigation skills in learners. Educators also need skills in developing the assessment rubrics, planning and assessing practical investigations and research projects. In this regard, Schreuder (1999:83) argues that “the effective implementation of curriculum presupposes clear understanding and preparation of teacher”. He further states that the effective implementation of a curriculum also “includes conceptual understanding, the availability of materials and ongoing support. It also presupposes good subject knowledge”. In the same vein Christie (1999) states that working with the principles of OBE requires well-prepared teachers who are likely to be found in former Model C schools. It is further stated that “teachers are struggling to come to grips as to what is really expected from them and hence most of the classroom interaction is still dominated by talk and chalk” (Vinjefold & Taylor, 1999:138).

Educator preparedness and professional development is not the only factor that affects learner achievement in physical science. They also need facilities and resources to teach without frustrations. In this regard, De Waal (2004:63) is of the opinion that “lack of appropriate learning support material further frustrates teacher as well as learners”. This also hinders effective classroom practice insofar as it restricts the learner’s visual perspectives as well as self-learning abilities.

Through the appropriate research procedures, this study will investigate the appropriate teaching and learning strategies to alleviate the conceptual difficulties and alternative conceptions in mechanics.

The Figure 1.1 below shows the pass rate of learners in physical sciences in Empangeni Education District in the year 2008 National Senior Certificate (NSC).



**Figure 1.1** *Empangeni Education District Physical Science Pass Rate 2008*

*Source: Department of Education, 2008 NSC results analysis.*

Figure 1.1 shows that Empangeni Education District achieved a percentage of 41.83%, that is, 3130 learners out of 7304 learners who wrote physical sciences passed and 4174 learners failed the subject.

Table 1.1 shows the generic rating scale used in the NCS for learner achievements from Grades 7 to 12 for all subjects.

**Table 1.1** *Empangeni District Physical Science Generic rating scale and Learner Achievement Levels for the NCS, 2008.*

<b>Rating/ Levels</b>	<b>Description</b>		<b>%</b>	<b>No of learners</b>	<b>% Achieved</b>
7	Outstanding achievement	All aspects of all assessment standards attained	80 – 100	14	0.19
6	Meritorious achievement	Almost all of aspects of assessment standards attained	70 – 79	57	0.78
5	Substantial achievement	Key aspects of all assessment standards achieved	60 – 69	145	1.99
4	Adequate achievement	Key aspects of most assessment standards achieved	50 – 59	301	4.12
3	Moderate achievement	At least half the assessment standards achieved	40 – 49	773	10.58
2	Elementary achievement	A negligible number of assessment standards achieved	30 – 39	1840	25.19
1	Not achieved	No achievement	0 – 29	4174	57.15
			Total	7304	100

Table 1.1 indicates pass rate in physical science according to levels of achievement used in the NCS for the Empangeni Education District in the year 2008. Altogether, there were 7304 learners who wrote physical science in 2008. Out of these only 517 got grades between 4 and 7, representing adequate

achievement and higher. The general picture is that there was poor performance in physical science for the Empangeni Education District. The analysis revealed that out of 7304 learners who wrote physical sciences, only 14 (0.19%) learners obtained the rating level 7 (80 – 100%), 57 (0.78%) learners achieved the rating level 6 (70 – 79%), 145 (1.99%) learners managed to get the rating level 5 (60 – 69%), 301 (4.12%) learners obtained the rating level 4 (50 – 59), 773 (10.58%) learners achieved the rating level 3 (40 – 49%) and 1840 (25.19%) learners achieved the rating level 2 (30 – 39%) (Department of education, 2008). The majority 4174 (57.15%) of the learners fell under the rating level 1 (0 – 29%). According to the NCS promotion requirements, the rating level 1 is interpreted as 'not achieved'. This indicates that 4174 (57.15%) learners failed physical science, that is, they did not achieve any Learning Outcome (LO) and Assessment Standards (ASs) expected to be achieved in physical science. Among those who passed physical sciences, most of them passed with the rating level 2 (30 – 39%) and there were 1840 (25.19%). These levels of achievement are not accepted by any institution for admission or employment. A few may consider level 3.

It can therefore be concluded that there was poor performance in physical science in the Empangeni Education District in the NSC of 2008. There may be a number of factors that contributed to this poor achievement.



Table 1.2 shows the Empangeni District Physical Science Generic rating scale and Learner Achievement Levels for the NCS, 2009 (Department of Education, 2009).

**Table 1.2** *Empangeni District Physical Science Generic rating scale and Learner Achievement Levels for the NCS, 2009.*

<b>Rating/ Levels</b>	<b>Description</b>		<b>%</b>	<b>No of learners</b>	<b>% Achieved</b>
7	Outstanding achievement	All aspects of all assessment standards attained	80 – 100	03	0,04
6	Meritorious achievement	Almost all of aspects of assessment standards attained	70 – 79	22	0,32
5	Substantial achievement	Key aspects of all assessment standards achieved	60 – 69	83	1,20
4	Adequate achievement	Key aspects of most assessment standards achieved	50 – 59	248	3,58
3	Moderate achievement	At least half the assessment standards achieved	40 – 49	664	9,58
2	Elementary achievement	A negligible number of assessment standards achieved	30 – 39	1178	16,98
1	Not achieved	No achievement	0 – 29	4736	68,30
			Total	6934	100

Table 1,2 also indicates the pass rate in physical science according to levels of achievements used in the NCS for Empangeni Education District in the year 2009. According to Table 1.2, there were 6934 learners who wrote physical science. The rating level 1 (0 -29%) is taken as a not achieved level. Table 1.2 reflects that there were 4736 that fell under this category in 2009. There were 4736 (68,30%) learners who performed poorly in physical science. The difference between the number of learners who wrote and the number of learners who performed poorly gives the number of learners who passed, that is, 2198 (31,70%) learners. There were 3 (0.04%) learners obtained rating level 7 (8 - 100%) and 22 (0,32%) learners obtained rating level 6 (70 – 79%). Table 1,2 also reflects that there was no improvement in the performance of learners in physical science in 2009 as compared to 2008. In 2009 the number of learners who performed poorly increase to 68,30% from 57,15% (in 2008). The general picture is that in 2009 the performance of learners in physical science was poorer.

Table 1.3 shows the Empangeni District Physical Science Generic rating scale and Learner Achievement Levels for the NCS, 2010 (Department of education, 2010).

**Table 1.3** *Empangeni District Physical Science Generic rating scale and Learner Achievement Levels for the NCS, 2010.*

<b>Rating/ Levels</b>	<b>Description</b>		<b>%</b>	<b>No of learners</b>	<b>% Achieved</b>
7	Outstanding achievement	All aspects of all assessment standards attained	80 – 100	62	0,90
6	Meritorious achievement	Almost all of aspects of assessment standards attained	70 – 79	109	1,58
5	Substantial achievement	Key aspects of all assessment standards achieved	60 – 69	245	3,55
4	Adequate achievement	Key aspects of most assessment standards achieved	50 – 59	457	6,62
3	Moderate achievement	At least half the assessment standards achieved	40 – 49	786	11,38
2	Elementary achievement	A negligible number of assessment standards achieved	30 – 39	1644	23,80
1	Not achieved	No achievement	0 – 29	3604	52,18
			Total	6907	100

In the same way, Table 1,3 indicates the pass rate in physical science according to levels of achievements for the year 2010. There were 6907 learners who wrote physical science for the National Senior Certificate (NSC). There were 3604 (52,18) learners who performed poorly during the NSC examinations in physical science. Again, The difference between the number of learners who wrote and the number of learners who performed poorly gives the number of learners who passed, that is, 3303 (47, 82%) learners. Table 1,3 reflects that

there was a significant improvement in the performance of learners in physical science in 2010 as compared to 2008 and 2009. However, there were still many learners who performed poorly. In 2010, there were 3604 (52, 18%) learners who performed poorly. There were 62 (0.90%) learners obtained rating level 7 (8 - 100%) and 109 (1,58%) learners obtained rating level 6 (70 – 79%). Again, the general picture is that there was poor performance in physical science for the Empangeni Education District in 2010.

Department of Education (2011) reports that the statistics for Empangeni Education District 2011 NSC results analysis for physical science reveal that altogether there were 6651 learners who wrote physical science. With regard to the learners who passed and those who performed poorly for the years 2010 and 2011, the trend was more or less the same. There were 3191 (47,98%) learners who passed and 3460 (52,02%) learners who performed poorly in 2011. There were 56 (0.84%) learners who achieved rating level 7 (80 – 100 %) (Department of Education, 2011). The trend that exists when comparing these four years, that is, 2008, 2009, 2010 and 2011, is that physical science learners in Empangeni Education District performed poorly in the NSC examinations.

## **1.4 THE AIMS OF THE STUDY**

The aims of this study were to determine the conceptual difficulties and also to identify the alternative conceptions in grade 12 physical science, particularly in mechanics. The study further sought to develop and implement curricular interventions based on traditional, OBE and blended approaches as well as to ascertain the effectiveness of the interventions developed and implemented. Accordingly, and as part of the aims, the conceptual difficulties and alternative conceptions were identified and three streams of curricular interventions were developed. Hence, this was an intervention study that sought to provide solutions to the stated problem.

#### 1.4.1 RESEARCH QUESTIONS

The principal objective of this study was to find answers to the following critical research questions:

- 1.4.1.1 What are the conceptual difficulties experienced by Grade 12 physical science learners in mechanics?
- 1.4.1.2 What are the most prevalent alternative conceptions relating to mechanics amongst Grade 12 physical science learners?
- 1.4.1.3 Which intervention(s) among the traditional, OBE-based and the Blended can best alleviate the conceptual difficulties and alternative conceptions relating to mechanics for grade 12 physical science learners?

#### 1.4.2 RESEARCH OBJECTIVES

Pursuant to the above aim, this study sought to address the following research objectives:

- 1.4.2.1 To determine the conceptual difficulties in mechanics which were experienced by Grade 12 physical science learners.
- 1.4.2.2 To identify the most prevalent alternative conceptions on mechanics amongst the Grade 12 physical science learners.
- 1.4.2.3 To develop and implement curricular interventions, based on the traditional, OBE and the Blended approaches, to alleviate the identified conceptual difficulties and alternative conceptions.

1.4.2.4 To ascertain the effectiveness of the interventions developed and implemented in 1.4.2.3 above.

### 1.4.3 STATISTICAL HYPOTHESES

Research questions 1.4.1.1 and 1.4.1.2 were addressed through review of literature, paper-pencil testing and content analysis. However, in order to address research question 1.4.1.3 a number of statistical hypotheses were generated for statistical testing. In each case, the 95% level of significance (that is,  $\alpha = 0,05$ ), and the relevant degrees of freedom were used in determining whether or not the requirements of statistical significance had been met. The hypotheses were stated as follows:

- 1.4.3.1 An intervention based on a traditional instructional approach has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- 1.4.3.2 An OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- 1.4.3.3 A Blended instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions in mechanics of grade 12 learners.
- 1.4.3.4 There is no statistically significant difference amongst OBE-based, traditional and blended instructional interventions in alleviating the conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.

The generic term *science* was used interchangeably with *physical science or physical sciences* in this study.

## 1.5 THE SIGNIFICANCE OF THE STUDY

The general picture for the NSC results analyses reported in section (statement of the problem) is that was poor performance in physical science for Empangeni Education District, that for the year 2008, 2009, 2010 and 2011. According to Delport and Mangwaya (2008:222),

Research has shown that learners' academic achievements are affected by numerous factors, including the intrinsic motivation of the learners, the learner's attitude to learning, the learner's cognitive abilities, the socio-economic background of the learner, the family structure, parents' literacy levels and their involvement in the learner's schooling, the school-type, the teacher-profile, the teaching and learning resources available, the climate at school, how the school networks with other institutions in society, the underpinning philosophy which guides the curriculum, and so forth.

They further posit that "learner achievement, and in particular Grade 12 results, are normally perceived to reflect the general standard of teaching and learning, not only in a particular school but also in a particular country" (Delport & Mangwaya, 2008:221). This view is further supported by Christie, Butler and Potterton (2007:55) in their observation that "one troubling issue in South Africa is the unsatisfactory level of learners' academic achievement, specifically in black secondary schools". Furthermore, Delport and Mangwaya (2008:220) state that "the academic achievement of learners at remote secondary schools in developing countries...tends to be low compared to those who attend urban schools". Research reveals that the training of Mathematics, Physical Science and Biology teachers is inadequate in quality (Arnott, Kubeka, Rice & Hall, 1997; Mailula, 1995; Ngoepe, 1995).

Properly educated young people are a need in any country since young people have the potential to contribute to the economic and social growth and wellbeing of a country (Delport & mangwaya, 2008). accordingly, "the need for well-trained

and educated young people in developing countries, such as South Africa, is even more significant” (Delpont & Mangwaya, 2008:221). The beneficiaries of this study are therefore, the Department Officials (Subject Advisors), professional practioners, and physical science learners. This study also sought to extend the boundaries of knowledge and understanding in the field of science education in respect of improving the learning and teaching of mechanics.

Poor performance by Grade 12 physical science learners motivated the researcher to undertake this study. The main purpose of the study was to improve learner achievement in physical science at Grade 12 level, with specific reference to mechanics.

## **1.6 METHODS OF STUDY**

This study used mixed methods research by combining both quantitative and qualitative methods. According to Johnson, Onwuegbuzie and Turner (2007), different researchers define mixed methods research in different ways. It is however noted that all these definitions converge at one point by combining qualitative and quantitative research methods in data collection and/or data analysis techniques.

According to Rossman and Wilson (1985) there are three reasons for combining quantitative and qualitative research:

- to enable corroboration of of different approaches through triangulation;
- to enable, or to develop, analysis in order to provide richer data; and
- to initiate new modes of thinking by attending to paradoxes that emerge from the two data sources.

To address the first and the second research questions, the researcher used qualitative research method to:

- Collect biographical information of learners, and their



- preferences on teaching methods, especially their opinions and comments on OBE and blended teaching approaches to teaching and learning;
- Identify the conceptual difficulties in mechanics with regard to “work and energy” through learners’ motivations, statements and comments;
  - Identify the alternative conceptions in mechanics with regard to “projectile motion, force and Newton’s Laws through learners’ motivations, statements and comments; and
  - Interpret and categorise all motivations qualitatively in accordance with emerging themes.

The quantitative research approach was used for the following aspects of the research:

- Marking: marks were allocated for the intended response, for any self-rating and for any motivation;
- Analysis: analysis of the multiple choice answers which was then followed by statistical testing;
- Statistical hypotheses: the third research question required the statistical analysis of the learners’ test scores as the hypotheses were related to it (third research question); and
- Motivations: open-ended motivations were analysed both qualitatively and quantitatively.

#### 1.6.1 RESEARCH DESIGN

Schumacher and McMillan (1993: 31) refer to research design as “the plan and structure of the investigation used to obtain evidence to answer research questions”. In this regard, “research design may be seen as the consideration and creation of means of obtaining reliable, honest, transferable and valid data, by means of which pronouncements about the phenomenon may be confirmed or rejected”. In concurrence, McKendrick (1987:256) posits that “research design is an overall plan or strategy by which questions are answered where a hypothesis is tested”.

This study is largely located within “the pragmatic paradigm, as it combined both qualitative and quantitative research methods” (Morgan, 2007:72). The research sample constituted 140 physical science learners selected from four (4) high schools in the Empangeni Education District. One hundred and forty (140) learners were considered sufficient for this study and hence, thirty five (35) learners from each of the four schools were included in the sample. According to Kumar (2005:168) “the greater the sample size, the more accurate will be the estimate of the true population mean”.

Non-probability sampling specifically known as convenience sampling was used to select schools. Convenience sampling “takes people or other units that are readily available” for selection (Leedy & Ormrod, 2005:206). Leedy and Ormrod (2005:206) further state that in non-probability sampling, the researcher has no way of forecasting or guaranteeing that each element of the population will be represented in the sample. Furthermore, some members of the population have little or no chance of being sampled (Leedy & Ormrod, 2005:206).

This study followed the experimental design specifically known as quasi-experimental non-equivalent comparison-group research design (Imenda & Muyangwa, 2006). In building up the instructional interventions that was used in this study, a Research and Development (R & D) protocol was also used. The identification of learners’ conceptual difficulties and alternative conceptions (established during Pilot study) was followed by three interventions – the traditional, (OBE) and the Blended approach (combination of many/several approaches) approach in order to determine which approach among the three better alleviated the conceptual difficulties and alternative conceptions in learners’ understanding.

### 1.6.2 LITERATURE STUDY

The purpose of the literature review was to provide the researcher with the means of getting to the frontiers in his field of knowledge, that is, science education, as suggested by Imenda and Muyangwa (2006:86). A general method, which entails literature review of the theoretical framework within which research re-formulates, was employed. This included a brief review of the constructivist and behaviourist theory paradigms and objectives as themes of the research study. For the purpose of this study, the literature survey was also used as a point of departure in an attempt to come up with a suitable model for physical science learner achievement for the KZN Province. McMillan and Schumacher (1993:113) content that literature study helps the researcher to:

- Define and limit the problem;
- Place a study in a historical associational perspective;
- Avoid unintentional replication;
- Select promising methods and measures; and
- Relate the findings to previous knowledge and suggest further research.

### 1.6.3 EMPIRICAL STUDY

An empirical study which entailed data collection and analysis was used in order to portray and present accurate assessment of the present situation with regard to the conceptual difficulty and alternative conceptions in mechanics for Grades 12 physical science curriculum. Such assessment could best be obtained by soliciting the opinions and perceptions of the officials of the Department of Education (Subject Advisors) involved with the NCS curriculum on one hand, and physical science educators as well as learners on the other, who are at the centre of the curriculum implementation in schools. The Basic Mechanics Test (BMT) that consisted of Section A and B was designed and distributed in person to four (4) selected schools. Section A included the biographical information, preference of instructional and evaluation methods as well as the determination of the familiarity of the learners about mechanics. Section B consisted only of

multiple choice questions that dealt with work, energy, projectile motion and force.

#### 1.6.4 RESEARCH INSTRUMENTS

The main instrument used was the BMT which was used as both pre- and post-test. Other instruments used during intervention were Grade 12 previous question papers that were used as classwork, homework and for the learners' discussions.

The BMT (Section A) was prepared and administered to Grades 12 physical science learners, from schools chosen at random, to determine their demographic characteristics. Pre-test instrument used to determine the current level of experience, knowledge, level of understanding of basic concepts and principles on mechanics topics identified earlier. It was also used to identify the specific conceptual difficulties and alternative conceptions in mechanics. Once the gaps, conceptual difficulties and alternatives have been established, an intervention model was developed in order to overcome the problem. The results of the initial tests were discussed among the physical science educators teaching grade 12. The fundamental concepts were re-taught. This constituted the first cycle of the research process. Post-test instrument was afterwards used to identify conceptual difficulties and alternative conceptions related to mechanics held by learners, which were resistant to change even after the interventions. Post-test instrument was also used to compare the effect of the interventions (traditional, OBE and Blended Approach) on alternative conceptions.

Regarding the traditional intervention, the concepts were treated according to traditional approach (behaviourist way of teaching and learning). Telling or lecturing method was mostly be used. With regard to OBE intervention, the concepts were treated according to the OBE approach (constructivist way of teaching and learning). Learners' questions, comments, responses in tests and during class were used. Instruction involved an open interaction among the educator and students, as well as learner-learner interactions. Regarding the

Blended approach to teaching and learning, concepts were taught using the combination of several other instructional methods.

#### **1.6.5 DATA ANALYSIS AND INTERPRETATION**

Data were analysed using the Statistical Package for Social Science Solution (SPSS). Both the qualitative and quantitative approaches were followed with respect to the analysis of all data that were gathered through the BMT.

### **1.7 DEMARCATION OF THE FIELD OF STUDY**

This study focused on alleviating conceptual difficulties and misconceptions in mechanics. The study aimed to develop strategies to improve learner achievement in physical science. Four (4) high schools at Empangeni Education District were selected as the research sample for the study. Empangeni Education District is one of the twelve (12) education districts in KwaZulu-Natal Province. There are four (4) education circuits at Empangeni Education District, that is, Lower Umfolozi, Mthunzini, Nkandla and Eshowe Education Circuit. Furthermore, the education circuits have wards of schools under them.

### **1.8 LIMITATIONS OF THE STUDY**

The following were the limitations of the study:

- 1.8.1 The sample of this study was drawn from schools in Empangeni Education District only; therefore, it was not representative of the entire population of learners in other education districts. Furthermore, the sample of this study consisted of four (4) high schools. This study was also limited to physical science learners since it is about the alleviation of the conceptual difficulties and alternative conceptions in mechanics. Mechanics is one of the six knowledge areas in physical sciences in the FET band.
- 1.8.2 This study focused on alleviating conceptual difficulties and misconceptions in mechanics.

## **1.9 DEFINITION OF TERMS**

### **1.9.1 INSTRUCTIONAL METHOD**

Instructional method is also referred to as instructional approach, or strategy, or mode. In the context of this study, instructional method refers to the way learning is presented to learners to bring conceptual change (Coetzee, 2008), that is, traditional, OBE and blended instructional methods.

### **1.9.2 BLENDED TEACHING AND LEARNING**

Blended approach to teaching and learning as defined by Imenda (2010:3) is “a mixing of different teaching / learning environments”. Imenda (2010:3) further posits that blended teaching and learning is mainly manifested in combining face-to-face instruction with computer-mediated instruction. Furthermore Imenda (2010:3) maintains that “teaching and learning tend to be more effective – mainly because different learners learn best through different approaches”. This study adopts this definition, whereby learners are exposed to different learning opportunities.

### **1.9.3 TRADITIONAL TEACHING METHOD**

In the traditional approach to teaching, the teacher is the active transmitter of information (Driver & Oldham, 1986; Wessel, 1999:1) and the information transmitted through lectures is passively absorbed by learners. The prescribed textbook is normally used as primary reference. According to this study, the lecturer and the textbook are the dominant instructional resources. The traditional instructional methods are more teacher-centred, e.g. lecture or telling method.

### **1.9.4 OUTCOMES-BASED EDUCATION (OBE)**

“OBE is an approach in an educational system where everything is defining, designing, building, focusing and organizing on the things of lasting significance that we ultimately want every learner to demonstrate successfully as the result of

their learning experiences” (Spady, 2008a:7, as cited by Coetzee, 2008). Marais (2009) states that OBE shifts the emphasis from what a pupil learns to how a pupil learns and explores the results of learning process. OBE approaches involve learner-centred methods, e.g. group discussions.

#### 1.9.5 PHYSICAL SCIENCES

All sciences are regarded as the result of human effort to understand the world around us (Kelder, 2005). The physical sciences are defined as the “fields of study that investigate the non-living parts of the universe” (Kelder, 2005: X). Kelder (2005: X) further defines physical sciences as “the study of what everything is made of, the structure and the properties of matter, the ways in which different kinds of matter interact, and different forms of energy”.

The Department of Education (2005) further describes physical sciences as dealing with needs of societies to understand how the physical environment works in order to benefit from it and responsibly care for it. All scientific and technological knowledge, including Indigenous Knowledge Systems (IKS), is used to address challenges facing the society. In the subject physical sciences, challenges such as the safe disposal of chemical waste, responsible utilization of resources and the environment, alternative energy sources are addressed (Department of Education, 2005:7).

According to the Department of Education (2005:29), the purpose of learning/teaching the physical sciences is to:

- Equip learners with investigative skills relating to physical and chemical phenomena;
- Promote knowledge and skills in scientific enquiry and problem solving, the construction and application of scientific and technological knowledge, an understanding of the nature of science and its relationship to technology, society and environment; and

- Prepare learners for future learning, specialist learning, employment, citizenship, holistic development, and environmental management.

Physical sciences build on the foundations laid by the natural sciences learning area in the General Education and Training (GET) band.

#### 1.9.6 CURRICULUM

The term curriculum can be defined in many ways at different contexts and levels, that is, national, school, subject and lesson level. The National Education Policy Initiative (NEPI) (1991:1) states that “the curriculum is central to the education process. Broadly defined, it refers to the teaching and learning activities and experiences which are provided by schools”. This definition further includes:

- The aims and objectives of the education system as well as the specific goals of schools;
- The selection of content to be taught, how it is arranged into subjects, programmes and syllabuses, and what skills and processes are included;
- Ways of teaching and learning, and relationships between teachers and learners (pedagogy); and
- The forms of assessment and evaluation which are used (NEPI, 1991:1).

A curriculum is an educational system which includes the programme of activities from which knowledge and skills can possibly be constructed. Driver and Oldham (1986:112) define curriculum as “educational system which includes the programme of activities from which knowledge and skills can possibly be constructed. Alternative conceptions are acknowledged”. In the context of this study, the term curriculum refers to a series of activities and teaching strategies to be employed during the three interventions to be developed, that is, traditional, OBE and blended interventions. .



### 1.9.7 ALTERNATIVE CONCEPTIONS

The term *alternative conceptions*, is preferred over misconceptions because the latter is judgmental in nature. The term alternative conception also confers respect on the learner who holds these ideas (Coetzee, 2008). Other words and phrases for alternative conceptions used by different authors include alternative frameworks, preconceptions, alternative conceptual frameworks, misconceptions, experimental knowledge, conceptual conflict, conceptual confusion, deep-seated difficulties (Kyk, Family & Shymansky, 1989; Mcdermott, 1993; Wandersee, Mintzes & Novak, 1994, cited in Coetzee, 2008).

### 1.9.8 CONSTRUCTIVISM

Constructivism is referred to as a theory of learning where students construct knowledge in the process of learning through social interaction and active participation with phenomena, as they develop shared meanings of a phenomenon via interactions within a social and cultural context (Coetzee, 2008, cited in Geer & Ridge, 2002). In constructivism, “an individual’s knowledge is not considered as a set of discrete bits, but as a series of structures” (Coetzee, 2008). The influences of alternative conceptions are recognized (Driver & Oldham, 1986).

### 1.9.9 MECHANICS

Mechanics is the branch of physics that deals with the study of the motion of objects, and the related concepts of force and energy. According to Giancoli (2000:15) “mechanics is customarily divided into two parts: kinematics, which is the description of how objects move, and dynamics, which deals with why objects move as they do”. As part of physics, therefore, mechanics can be understood through principles, laws and rules as well.

## 1.10 THE STRUCTURE OF THE THESIS

In an attempt to meet the aim of the study and address the problem in a scientific manner, it became necessary to organize the thesis in the form of chapters, each of which contributed to the holistic approach of investigating the problem and in developing mechanics in an effective NCS implementation model.

Therefore the chapters of this thesis will be organized as follows:

**Chapter One:** *Introduction*

**Chapter Two:** *Theoretical Framework and Review of Relevant Literature*

**Chapter Three:** *Research Methodology*

**Chapter Four:** *Results and Discussion*

**Chapter Five:** *Summary, Conclusions and Recommendations*

## 1.11 CONCLUSION

This chapter gave an overview of the whole study and also laid the background of the study. Part of this chapter was the statement of the problem, the aims and objectives of the study. A brief significance of the study was given. This chapter further briefly referred to the methodology. Demarcation of the field of study and the limitations of the study were indicated. The key terms or concepts were also defined and the structure of the study was outlined. The next chapter deals with the literature review.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 OVERVIEW**

This study focused on the conceptual difficulties and alternative conceptions in mechanics with particular reference to grade12 physical science. The scope of the problem under investigation has been outlined in the preceding chapter. This chapter develops and presents the theoretical and conceptual framework derived from the review of relevant literature, in line with the research questions of this study. The literature reviewed in this chapter revolves around the themes of the study, that is, (a) conceptual difficulties in mechanics, (b) alternative conceptions, (c) learning theories, (d) curriculum development, and (e) traditional, outcomes-based and the blended approaches to teaching and learning.

#### **2.2 CONCEPTUAL DIFFICULTIES IN MECHANICS**

Research reveals that learners have many well-known conceptual difficulties with basic mechanics (Kim & Pak, 2002). However, Kim and Pak (2002:2) further state that learners do not “have much difficulty in using physics formulas and mathematics”. Freedman (1996) also reports that students can usually handle problems that are akin to the worked examples in their textbook, especially if there are ‘special equations’ that they can use but problems that require using fundamental concepts, are another matter altogether. Freedman (1996:3) further states that “the proof of this statement is the difference between student performance on ‘standard’ physics problems that require computation and calculation and their performance on purely conceptual, qualitative problems”. Furthermore, Freedman (1996:3) posits that

part of the difficulty that students have with conceptual questions stems from the kind of problems that are most often assigned. Instructors

commonly assign homework and exam problems that involve computation and calculation, in the belief that these are 'real' physics problems.

As a way of alleviating conceptual difficulty, Freedman (1996:4) avers that if we truly want students to learn about the ideas of physics, we must require them to use these ideas in their homework and then hold them accountable for these ideas in examinations. Most introductory textbooks include a wealth of conceptual questions, and questions of this sort should be assigned regularly. ...conceptual questions are very useful tools for teaching and learning physics.

According to the NCS, there are six knowledge areas in physical sciences and mechanics is one of them. Mechanics carries more marks than any other single component of the NCS for physical science, and constitutes 33% of paper one (Physics) for the National Senior Certificate (NSC). There are themes in mechanics that need attention and learners do experience conceptual difficulties with them. The concepts experienced as difficult are: work and energy; force, momentum and impulse; weight and acceleration due to gravity; kinematics graphs; projectile motion; and frames of reference.

With regard to energy, Sefton (2004:7) opines that there are four fallacies about energy. Sefton (2004:7) argues that one of the four fallacies about energy is that "a particle can have potential energy." Sefton (2004:7) states that "when searching any elementary physics text it is found 'that a body such as a brick gains PE of  $mgh$  when it is lifted through a height  $h$ .' The argument is that "the serious error lies not in the concept of PE or the formula but in the subtle statement of ownership" (Sefton, 2004:7). According to Sefton (2004:7),

The proper view is that the change in PE belongs to the system of the brick and the Earth. The reason for that is that the PE arises from the gravitational interaction between that brick and the Earth. If it were not for the Earth there would be no PE... All potential energy arises from interactions between parts of a system.

A particular instructional strategy is needed to address such conceptions. Munson (1994:2) states that “science education research based on the constructivist model of learning has emphasised the importance of understanding students’ prior knowledge before beginning instruction.” Munson (1994:2) further states that “of particular importance to educators is the complex issue of student misconceptions.”

Bagno, Eylon and Ganiel (2000:2) in their study “describe a new program: MAOF (‘overview’ in Hebrew), relates large parts of mechanics and electromagnetism to each other via the key concepts of field and potential, and at the same time treats students’ conceptual difficulties”. According to their study,

The instructional model integrates problem solving, conceptual understanding, and the construction of a knowledge structure. It consists of five stages: solve, reflect, conceptualise, apply and link. In order to construct the relationships within a domain, students solve simple and familiar problems, reflect on their solution methods, identify the underlying principles, and represent them in visual form, forming concept maps. Additional activities deal with conceptual difficulties and application of the information represented in the concept map (Bagno, Eylon & Ganiel, 2000:2).

The findings of their study revealed that

Students who studied with MAOF significantly improved their understanding of central ideas associated with fields and potentials. They improved their understanding of understanding of the relationship between general concepts and their examples, and could better solve familiar and unfamiliar problems using these concepts (Bagno, Eylon & Ganiel, 2000:2).

The MAOF is therefore one of the strategies that can be used to alleviate the conceptual difficulties in mechanics.

The study by Leonard, Dufresne and Mestre (1996:2) report on the use of qualitative problem-solving strategies in teaching an introductory, calculus-based physics course as a means of highlighting the role played by conceptual knowledge in solving problems. Their research report reveals that

presenting strategies during lectures and homework solutions provides an excellent opportunity to model for students the type of concept-based, qualitative reasoning that is valued their profession, and that student-generated strategies serve as a diagnostic function by providing instructors with insights on students' conceptual understanding and reasoning (Leaonard, Dufresne & mestre, 1996: 2).

The findings of their study report that they found

strategies to be effective pedagogical tools for helping students both to identify principles that could be applied to solve specific problems, as well as to recall the major principles covered in the course months after it was over (Leaonard, Dufresne & mestre, 1996: 2).

### 2.2.1 CONCEPTUAL DIFFICULTIES ABOUT WORK AND ENERGY

Sefton (2004:3) states that “many tests give neat packaged definitions of energy such as ‘energy is the capacity to do work.’” Sefton (2004:4) further posits that “taken literally, definitions like that are at best misleading” and “at worst they are just plain wrong.” Furthermore Sefton (2004:3) avers that

the main argument against such a definition comes from thermodynamics. In thermodynamics *work* takes on a meaning which is broader than the ‘force times distance’ concept of classical mechanics. It refers either to a process of energy transfer or to the energy being transferred. It is therefore clear from this report that some conceptual difficulties exist in learners as a result of textbook with misleading information.

By way of alleviating conceptual difficulties about work and energy, Beatty, Gerace, Leonard and Dufresne (2006:2) in their study report that “classroom response systems can be powerful tools for teaching physics.” They further state

that ‘classroom response systems’ efficacy depends strongly on the quality of the questions” (Beatty, Gerace, Leonard & Dufresne, 2006:2). Furthermore, Beatty, Gerace, Leonard and Dufresne (2006:2) posit report that “creating effective questions is difficult and differs from creating examination and homework problems” (Beatty, Gerace, Leonard & Dufresne, 2006:2). For this strategy to be effective “each classroom response system question should have an explicit pedagogic purpose consisting of a content goal, a process goal, and a metacognitive goal” (Beatty, Gerace, Leonard & Dufresne, 2006:2).

It often proves advantageous in science to define quantities that are conceptual in nature. One of the most useful of these quantities is the concept of energy (Bueche, 1986:79). Koenig, Endorf and Braun (2007:1) report the findings of their study on ‘changes in energy and momentum’ that “the most effective teaching method was for students working in cooperative learning groups with the instructors questioning the groups using Socratic dialogue.” They used different teaching methods that varied in the amount of student and teacher engagement. The student understanding was evaluated through pre- and post-tests (Koenig, Endorf & Braun, 2007). Their study promotes interactive engagement of learners and their instructors. Learners should also be able to relate mechanical energy with the concept of work. Bueche (1986:79) states that “there are many colloquial meanings for the word work, for example we go to work in the morning; we work at our studies; we do all kinds of work”. The colloquial meanings may sometimes lead to alternative conceptions. Giancoli (2000:156) adds by stating that “the word work has a variety of meanings in everyday language but in physics, work is given a very specific meaning to describe what is accomplished by the action of a force when it makes an object move through a distance”. Bueche (1986:79) specifically defines work as follows:

“The work ( $\Delta W$ ) done by a force that acts on an object as the object moves through a small displacement  $\Delta s$ , is  $W = F_s \Delta s$ , where  $F_s$  is the component of the force  $F$  in the direction of the displacement”.

Giancoli (2000:156) defines work as the “product of the magnitude of the displacement times the component of the force parallel to the displacement”. It is therefore important to note that the component of the force should be the one parallel to the displacement. Learners tend to use the applied force without starting by first finding the component parallel to the displacement. The other mistake they make is of substituting any force to the equation,  $W = F_s \Delta s$ . It should be noted that work is a scalar quantity, since it does not have direction. From the defining equation, it is evident that work has the dimensions of force and displacement. In the International System of units (Système International) (SI), the unit of work is the Newton-metre (N m), which is called the joule (J).

There are two very important features to notice about the definition of work. First, in order that work is done, motion must occur. There must be displacement,  $\Delta s$ . In addition, the applied force must have a component  $F_s$  in the direction of the displacement or parallel to the displacement (Bueche, 1986:80). Bueche (1986:80) further states that “often the defining equation for work is written in a slightly different way because  $F_s = F \cos\theta$ , where  $\theta$  is the angle between the force  $F$  and the displacement  $\Delta s$ ” and hence the equation:  $\Delta W = (F \cos\theta) (\Delta s)$ . Furthermore, Bueche (1986:80) suggests a short hand for writing the equation:  $\Delta W = (F \cos\theta) (\Delta s)$  that involves what is called the scalar product of two vectors. This product is defined in the following way: Suppose two vectors  $A$  and  $B$  are orientated such that the angle between them is  $\theta$ . The scalar product of  $A$  and  $B \equiv A \cdot B \equiv AB \cos\theta$ . The result is a scalar, hence the name scalar product. The result is also referred to as the dot product. In terms of this short hand notation, the work  $\Delta W$  done by a force  $F$  in moving the object through a displacement  $\Delta s$ , is,  $\Delta W = F \cdot \Delta s = (F \cos\theta) (\Delta s)$ . Since the  $(F \cos\theta) (\Delta s) = (\Delta s) (F \cos\theta)$ ; the order in which a scalar product is written is unimportant. Therefore:  $F \cdot \Delta s$ .



$\Delta s = \Delta s$ .  $F$  and the scalar product is commutative. The scalar product defined by  $A \cdot B = AB \cos \theta$  is simply a short hand way of writing the quantity  $AB \cos \theta$ . In summary, work is  $\Delta W = F_s \Delta s = F \cdot \Delta s = F \Delta s \cos \theta$ . Where  $\theta$  is the angle between the force  $F$  and the displacement  $\Delta s$ .

When dealing with work, as with force, it is necessary to specify whether work is done, *by*, a specific object or, *on*, a specific object. It is also important to specify whether the work done is due to one particular force or to the total net force on the object.

### **Work Done by Stopping Force**

The work done by forces that tend to slow moving objects is unique: the work done by stopping force is negative. Consider the block sliding along a surface. Then, the only unbalanced force acting on it is the frictional force  $f$ . It is noted that the displacement  $\Delta x$  is in the positive  $x$  direction while the applied force is in the negative  $x$  direction. The angle between the displacement and the stopping force is  $180^\circ$ . To find the work done by the frictional force on the object:  $\Delta W = f \cdot \Delta x = f \Delta x \cos 180^\circ$ , but  $\cos 180^\circ = -1$  and so  $\Delta W = -f \Delta x$ . Therefore, the work done by frictional force, a stopping force, is negative. Bueche (1986:81) therefore states that “negative work is done on an object by a force that is opposite in direction to the motion of the object”. In particular, the frictional force that slows the sliding of an object over a surface does negative work on the object. A negative sign however, does not mean that work has changed from being a scalar quantity.

### **Work-Energy Theorem**

Giancoli (2000:165) states the work-energy theorem as follows: “The net work done on an object is equal to its change in kinetic energy”. The main challenges lie with the application of the theorem. The theorem is mathematically derived as follows:

$\Delta W = F x$ , according to Newton's second law,  $F = ma$ . Substituting  $ma$  for  $F$ , we get  $\Delta W = max$ . Taking the equation of motion,  $V_{f2}^2 = V_{i2}^2 + 2a x$ ; and make 'a' the subject of the formula, we get;  $a = (V_{f2}^2 - V_{i2}^2) / 2x$ , then substitute to  $\Delta W = max$ , we get  $\Delta W = m (V_{f2}^2 - V_{i2}^2 / 2x) x$ .

This brings us to,  $\Delta W = \frac{1}{2} mV_{f2}^2 - \frac{1}{2} mV_{i2}^2$ . We define the quantity  $\frac{1}{2} mV_{f2}^2$  to be the translational kinetic energy (K):  $K = \frac{1}{2} MV^2$ .

Learners have also a challenge in relating kinetic energy with mass and relating kinetic energy with velocity. In the kinetic energy equation, the relationship between kinetic energy, mass and velocity is as follows:

The kinetic energy is directly proportional to the mass of the object, and it is proportional to the square of the velocity of the object. Thus, if the mass is doubled, the kinetic energy is doubled. But if the velocity is doubled, the object has four times as much kinetic energy and is therefore capable of doing four times as much work. The connection between work and kinetic energy operates in both directions. If the net work  $W$  done on an object is positive, its kinetic energy increases, whereas if  $W$  is negative, its kinetic energy decreases. In the latter case, the object does positive work on something else. If the net work done on the object is zero, its kinetic energy remains constant (Giancoli, 2000:166).

Sefton (2004:4) states that "the idea of kinetic energy (KE) seems simple enough, but saying that it is  $\frac{1}{2} mv^2$  is only part of the story." Sefton (2004:4) further argues that

the formula applies, strictly, to the abstract notion of a particle. In that case the meaning of  $v$  is quite straightforward: it is the particle's speed. On the other hand, real bodies have structure and different parts of that structure may have different motions and different speeds. Clearly, it

could be a complicated business to calculate the total kinetic energy of a body.

Freedman (1996:4) opines that the “issue is the question of how students deal with formal, mathematical expressions of physical concepts”. To further explain this, Freedman (1996:4) uses two examples, that is, Newton’s second law and the work-energy theorem as follows:

$$F = ma, \quad (1)$$

$$W_{\text{net}} = \Delta K = \frac{1}{2} mv_{\text{final}}^2 - \frac{1}{2} mv_{\text{initial}}^2. \quad (2)$$

It is very common for students to interpret Eq. (1) to mean that the product of a body’s mass and its acceleration is itself a force. In other words, they fail to realize that a mathematical equality between two quantities does not imply that the two quantities are conceptually distinct. As a result, they do not appreciate that acceleration is the consequence of the presence of a net force. Thus students frequently make reference to such chimera as “the force due to acceleration” or “the force due to momentum”.

A similar confusion arises concerning the work-energy theorem, Eq. (2). When students are asked to explain what kinetic energy means, the most common response is that it is “one-half the mass times the speed squared.’ By fixating on the mathematical definition, they fail to grasp the essence of the work-energy theorem that the kinetic energy of a particle is equal to the total work that was done to accelerate it from rest to its present speed, and equal to the total work that the particle can do in the process of being brought to rest.

The study by Arons (1999:2) on the development of energy concepts in introductory physics courses reveals that “the work-energy theorem, derived from Newton’s second law, applies to the displacement of the particle or the centre of mass of an extended body treated as a particle.” Arons (1999:2) further states that the work-energy theorem is not a valid statement about energy

transformations when work is done against a frictional force or actions on or by deformable bodies. Furthermore, Arons (1999:2) posits that “to use work in conservation of energy calculations, work must be calculated as the sum of products of forces and their corresponding displacements at locations where the forces are applied at the periphery of the system under consideration.”

According to Arons (1999:2)

failure to make this conceptual distinction results in various errors and misleading statements widely prevalent in textbooks, thus reinforcing confusion about energy transformations associated with the action in everyday experience of zero-work forces such as those present in walking, running, jumping, or accelerating a car.

One way of alleviating the conceptual difficulties with regarding to energy is to use multiple-representation method as used by Van Heuvelen and Zou (2001). In their study they state that “an energy process can be represented by verbal, pictorial, bar charts, and mathematical representations” (Van Heuvelen & Zou, 2001: 1). They further opine that “assessment indicates that the method, especially the qualitative work-energy bar charts, serves as a useful visual tool to help students understand work-energy concepts and to solve related problems” (Van Heuvelen & Zou, 2001:1).

Educators need to see to it that learners truly learn how to use the concepts of physics, in order that they may learn to think like scientists or engineers (Freedman, 1996).

### **The Principle of Conservation of Mechanical Energy and Linear Momentum**

In the researcher’s experience, with regard to the principle of conservation of energy and momentum, learners have no problem in stating them in words. However, most times they fail to apply these laws due to the lack of understanding of the principles, especially the following concepts: ‘conservation’, ‘system’, and ‘isolated system’. Legge and Petrolito (2004:2) posit that

“discussions regarding the misconceptions students develop about work and conservation of energy has focused attention on introductory mechanics.” Giancoli (1991:136) states that “in everyday usage, conservation means, ‘saving’ or ‘using wisely’ – as when it is said that we should conserve energy. In physics the word conservation refers to a quantity that remains strictly constant”. Sefton (2004:4) posits that “to physicists the keystone of the vast energy concept is conservation. Without conservation energy would mean nothing.” Sefton (2004:4) further opines that

a severe problem for teachers is that the word conservation has two quite different meanings, even with science lessons. To a physicist, conservation of energy means that energy calculations, correctly performed, always balance to give a constant total. To most literate people, including many science teachers, conservation means saving energy or not waisting.

Teachers are sometimes sources of conceptual difficulty.

In this case, the law of conservation of energy can be stated in the following way:

The total energy is neither increased nor decreased in any process. Energy can be transformed from one form to another, and transferred from one body to another, but the total amount remains constant (Giancoli, 2000: 190).

Mathematically, the same law can be stated in the following way: Kinetic Energy (K) + Gravitational Potential Energy (U) = constant, that is, the sum of the kinetic plus potential energies of an object or system of objects, which is called the total mechanical energy, remains constant (Giancoli, 2000:190). Giancoli (2000:209) further states that a ‘system’ is a “set of objects that interact with each other”. Furthermore, Giancoli (1998:183) defines an isolated system as “one in which the only forces present are those between the objects of the system: that is, there is no net external force”. This implies that if external forces do act, that is,

forces exerted by objects outside the system, then momentum or energy may not be conserved. Thus, the conservation of momentum principle will only apply if the system is redefined so as to include the other objects.

With regard to the concept of conservation of mechanical energy, Mestre (2002:1) “reports on two experiments in which high-performing university having finished an introductory physics course were asked to pose mechanics problems (e.g. conservation of mechanical energy, Newton’s Second Law)”. The findings of this study by Mestre (2002:1) reveal that, “when followed by an interview, problem posing is a powerful assessment tool for probing students’ understanding of physics concepts, as well as their ability to transfer their knowledge to novel contexts”. Mestre (2002:1) further reports that “in many instances, students posed appropriate, solvable problems, yet displayed major flaws in conceptual understanding”. Furthermore, Mestre (2002:1) “suggests that that even good novices are lacking in the way their conceptual knowledge is organised in memory and linked to contexts and procedures”. Problem posing can be used as a pedagogical tool in alleviating conceptual difficulties about conservation of mechanical energy.

### 2.2.2 CONCEPTUAL DIFFICULTIES ABOUT PROJECTILE MOTION

In the experience of the researcher, the most difficult concept for learners with regard to free falling and projectile motion is the direction of the acceleration due to gravity. By way of definition, projectile motion refers to the motion of an object that is projected into the air at an angle (Giancoli, 1998:59). Giancoli (2000) further maintains that a projectile motion is a motion of an object moving in an arc above the earth’s surface and can be analysed as two separate motions when air resistance is ignored. The horizontal component of motion is at constant velocity, whereas the vertical component is at constant acceleration (due to gravity),  $g$ , just as for a body falling vertically under the action of gravity (Giancoli, 2000). In the same way, a trajectory is defined as a path that is followed by a projectile. Thus, a projectile is an object that is thrown into the air. Learners also

experience problems with regard to drawing the graphs of these motions, that is, free falling and projectile motion, especially the position versus time, velocity versus time, acceleration versus time, speed versus time, distance versus time graphs, etc. With regard to free falling bodies, Bueche (1986:45) states that if the effects of friction due to air can be ignored, then all bodies fall to the earth with the same acceleration. This acceleration (due to gravity) is about,  $9.8 \text{ m.s}^{-2}$ . However, the acceleration due to gravity varies slightly from place to place (Bueche, 1986:45). Bueche (1986:46) further states that like all other accelerations, the acceleration due to gravity is a vector. By way of definition, a vector is a physical quantity that has both magnitude and direction, for example, force, momentum, velocity, displacement, etc.

Consequently, falling objects speed up and rising objects slow down. In the latter case the acceleration due to gravity is in the opposite direction of the motion and therefore acts to slow down the motion (Bueche, 1986:46). Learners have difficulty in using signs for motions that involve two opposite directions. On this note, Bueche (1986:46) warns that care must be taken in dealing with motions which involve both up and down motion since the proper use of signs is of great importance. Thus, the choice of signs for each direction before any drawing or calculation is done is important, that is, choosing + direction as up or down, but consistency about signs throughout the drawing or calculation is essential. Whether the signs (positive and negative) are indicated in graphs or in calculations, learners tend to confuse or attach signs to the number as if in mathematics rather than relating signs to directions. For example, +5 m and -3 m, to learners it appears as if 5 m is greater than 3 m, whereas this means 5 m and 3 m in opposite directions.

Another area of difficult is in dealing with projectile motion in two dimensions. Bueche (1986:48) states that “an object (a projectile) undergoing both vertical and horizontal friction-free motion above the earth undergoes two simultaneous independent motions.” Bueche (1986) further opines that the projectile moves

horizontally with constant speed and at the same time, it moves vertically in a way a similar object not undergoing horizontal motion would move.

Giancoli (2000:34) also gives caution with regard to velocity and acceleration:

“Two common misconceptions; (1) that acceleration and velocity are always in the same direction, and (2) that an object thrown upward has zero acceleration at the highest point”. For example, a person throws a ball upward into the air. It follows that when the ball is moving upward, its velocity is positive (when upward is chosen as positive); although the acceleration is negative (downward); in the downward flight, both velocity and acceleration are negative (downward). Furthermore, Giancoli (2000) posits that as to the second possible misconception, at the highest point, the ball pauses momentarily and so its speed is zero. Learners tend to think that the acceleration is also zero at the highest point. This thinking leads to an alternative conception about acceleration of the ball at the highest point. The thinking that  $a = 0$  at the highest point also leads to the conclusion that upon reaching the highest point, the ball would hover there. For, if the acceleration, which is the rate of change of velocity, were zero, the velocity wouldn't change. The velocity would remain zero.

This section has reviewed mechanics concepts that present some difficulties to grade 12 physical science learners. These concepts are energy, work, force, work-energy theorem, principle of conservation of mechanical energy, projectile motion and linear momentum. The areas which present some conceptual difficulties to learners in each concept were highlighted. Literature reveals that a high percentage of learners do not understand some of the key concepts of energy (Goldring & Osborne, 1994). The study done by Kim and Pak (2002) shows that students do not have much difficulties in using physics formulas and mathematics. However, they found that students still had many of the well-known conceptual difficulties with some basic mechanics (Kim & Pak, 2002).



Domenech, Gal-Perez, Gras-Marti, Guisasola, Martinez-Torregrosa, Salinas, Trumper, Valdes and Vilches (2007) also report that the growing awareness of serious difficulties in the learning of energy issues has produced a great deal of research, most of which is focused on specific conceptual aspects. In their opinion, the difficulties pointed out in the literature are interrelated and connected to other aspects (conceptual as well as procedural and axiological). Conceptual difficulties in mechanics may lead to alternative conceptions. Alternatively, McCloskey (1983) postulated that physics students have difficulties in understanding the principles of motion because of the intuitive alternative conceptions. On the other hand, therefore, alternative conceptions in mechanics may lead to conceptual difficulties.

### **2.3 ALTERNATIVE CONCEPTIONS IN MECHANICS**

Coetzee (2008) affirms the view that learners do not come to class with empty minds, because they develop beliefs about things that happen in their surroundings from the very earliest days of their lives. This view is supported by cognitive scientists (scientists who study how people learn). Who posit that physics students come to class with a set of beliefs which they are unwilling to (or not easily willing) discard despite evidence to the contrary (Oliver, 1992). In the same way, learners come to the physical science class with already strongly held ideas, which may differ from the theories the educator may wish to develop. The strongly held ideas may sometimes hinder learning. Driver (1983) also avers that alternative conceptions, once formed, influence learner's observations and the sense they make of further learning. She further states that these alternative conceptions are resistant to change, making a considerable number of learners hold on to certain intuitive notions despite the science teaching they receive in school. Physical science educators have a task of identifying the sources and origins of alternative conceptions.

### 2.3.1 ORIGIN OF ALTERNATIVE CONCEPTIONS

Coetzee (2008), reports that textbooks, as one of the main sources of students' knowledge, were a major contributor to the existence of alternative conceptions. Coetzee (2008) further posits that the common origin of alternative conceptions could be any previous experience or observation by the learner, not necessarily arising out of formal training, but any life experience. Oliver (1988) adds by stating that alternative conceptions are also a function of other variables in the education process, including the teacher, the curriculum, social factors, affective factors, emotional factors, motivation, attitudes, and possible interactions among these variables. The study done by Schoon (1998) revealed that also teacher hold alternative conceptions. Schoon (1998) discovered that the holding of certain alternative conceptions was associated with persons of low self-efficacy. The study done by Schoon (1995) also suggests that many alternative conceptions originate in the classroom and that pre-service elementary education teachers have many of the same alternative conceptions that their future students will have. Learners do not make mistakes because they are stupid – their mistakes are rational and meaningful efforts to cope with science. Ginsburg (1977) states that these mistakes are derivations from what learners have been taught. He further state that these derivations are objectively illogical and wrong, but psychologically, from the learners' perspective, they make a lot of sense.

On the other hand, Oliver (1988) holds the view that any new learning depends on previous learning in the following ways:

- Correct new learning depends on previous correct learning;
- Incorrect new learning is often the result of previous incorrect learning, and in the same way;
- Incorrect new learning is mostly the result of previous correct learning;
- Every alternative conception has a legitimate origin in the previous correct learning – each alternative conception was correct for some earlier task, as performed in some earlier domain of the curriculum; and

- The source of alternative conceptions is mostly an overgeneralisation of previous knowledge (that was correct in an earlier domain), to an extended domain (where it was not valid).

To further clarify Oliver's views, traditionally, it was correct and accepted to write the unit for the speed as,  $\text{m.s}^{-1}$ ; for acceleration as,  $\text{m.s}^{-2}$  plus direction; etc, but in the new curriculum, that is, NCS, it has been reviewed and hence not correct and unaccepted. The accepted way of writing the units is  $\text{m.s}^{-1}$ , for speed;  $\text{m.s}^{-2}$  plus direction, for acceleration; etc. The only difference is the position of the dot that represents multiplication. Traditionally the dot was written as a full stop, whereas in the new curriculum the dot is written in the middle to distinguish it from a full stop. Learning is therefore not static but progressive and dynamic. There should therefore be exercises that are intentionally designed to diagnose and discriminate alternative conceptions. There should also be a way of overcoming the alternative conceptions in learners.

### 2.3.2 OVERCOMING ALTERNATIVE CONCEPTIONS

The tasks of overcoming alternative conceptions involve becoming aware of the misconceptions, considering alternative conceptions or explanations, making a personal evaluation of the two competing ideas and adopting a new conception that is more plausible than the previously held misconception. This system involves self-reflection (to ponder on your own belief systems), critical thinking (to analyse the reasonableness of two competing ideas), and evaluation (Oliver, 1992).

Schoon (1995:2) argues that "understanding how alternative conceptions are formed can make it easier for classroom teachers to help their students uncover their own alternative conceptions". Schoon (1995:2) further asserts that "teacher, however, cannot be expected to help children with alternative conceptions if they hold these alternative conceptions themselves". One way of overcoming alternative conceptions is for science educators to teach missing concepts, teach

and re-teach the correct concepts or procedures directly. Schoon (1998) also posit that teachers and teacher educators need to place a greater emphasis on the understanding of basic but critical conceptions of science. As another way of overcoming alternative conceptions, Jimoyiannis and Komis (2001:1) suggest that science educators use computer simulations as an alternative instructional tool, in order to help students confront their cognitive constraints and develop functional understanding of physics. Ozmen, Demircioglu and Demircioglu (2009) in their study on “the effect of conceptual change texts accompanied with computer animations on overcoming 11<sup>th</sup> grade students’ alternative conceptions of chemical bonds”, suggest that conceptual change texts combined with computer animations can be effective instructional tools to improve students’ conceptual understanding of science concepts.

Clement (2006) in his study designed lessons to deal with students’ alternative conceptions in three areas of mechanics: static normal forces, frictional forces, and Newton’s third law for moving objects. In his study, “instructional techniques such as class discussions of the validity of analogy between a target problem and an intuitive anchoring example, and forming a structural chain of intermediate bridging analogies were used. To overcome the alternative conceptions relating to force and Newton’s third law, Clement (2006) suggests that researchers and curriculum developers should focus at least as much attention on students’ useful prior knowledge as they are on students’ alternative conceptions. Oliver (1988) states that a schema acquired early and developed well are highly resistant to change. Children do not easily accommodate new ideas when necessary, that is, change their present schemas, but rather assimilate new ideas into existing schemas, which means that the new idea must be ‘like’ a previous idea. He further holds that traditionally, the university blames the high school for poor teaching, the high school blames senior primary, who in turn blame junior primary, who blame the home.

On the other hand, from a constructivist perspective, alternative conceptions are crucially important to learning and teaching, because they form part of a learner’s

conceptual structure that will interact with new concepts and influence new learning, mostly in a negative way, because alternative conceptions generate errors (Oliver, 1988). Furthermore, from a constructivist perspective, the teacher cannot transmit ready-made (that is, cannot construct knowledge for the learner) and intact knowledge to the learner. Errors and alternative conceptions are seen as the natural result of learners' efforts to construct their own knowledge, and these alternative conceptions are intelligent constructions based upon correct or incomplete (but not wrong) previous knowledge. Alternative conceptions, therefore, cannot be avoided. Such errors, arising out of alternative conceptions, should not be treated as terrible things to be uprooted, since this may confuse the learner and shake his/her confidence in his/her previous knowledge. Instead, making errors is best regarded as part of the process of learning. Physical science educators should therefore create a classroom atmosphere that is tolerant of errors and alternative conceptions and exploit them as opportunities to enhance learning. In this regard, direct teaching (telling) of missing concepts will not do. Rather, teachers should help learners to connect new knowledge to previous learning. Swan (1983), Nesher (1987) and Oliver (1988) describe a teaching approach that is designed to expose learners' misconceptions and provide a feedback mechanism that leads to cognitive conflict. Discussion, communication, reflection, and negotiation of meaning are essential features of a successful approach to resolve learners' alternative conceptions.

Collaborative learning can also be used to enable learners to learn together. It also makes learners more active and self-reliant. Also "the active, collaborative, reflective re-examination of ideas in a social context is one of the most important remedies for combating the illusion of misunderstanding and persistence of misconceptions" (Schulman, 1999). In the same vein, Coetzee (2008:88) posits that "collaboration is a powerful stimulus for the reflection which is fundamental to change beliefs, values and understanding".

However, collaboration needs to be structured and built. A collaboration structure is based on three components, as envisaged by Alonso, Lopez, Manrique and Vines (2005:230):

- Collaborative Activities

The following are guidelines for designing activities:

- Relate collaborative activities to the learning objectives;
- Prepare assignments that require collaboration;
- Size groups and backgrounds of participants to optimise interactions.
- Structure group assignments around products (i.e a project) or processes (i.e. a problem-based learning).

- Participants

Palloff and Pratt (2003, as cited by Alonso et al, 2005:230) discuss best characteristics of students to include: openness, flexibility and humour, honesty, and willingness to work collaboratively. They further maintain that the spirit of collaboration is fundamental to a successful learning community – where participants need to be committed:

- to be respectful of other participants;
- to do a fair share of work; and
- to help each other and provide feedback when testing ideas or knowledge.

- Instructor

To be efficient in developing collaborative learning in the implementation phase, the instructor should:

- make everyone feel welcome;
- express himself or herself with clarity to avoid misunderstanding;
- teach how to build collaboration;
- invite students to participate;
- give feedback as soon as possible;
- moderate actively but not dominate;

- be a model to imitate; and
- set limits when participation is in the wrong direction.

Hestenes, Wells and Swakhamer (1992) posits that alternative conceptions can be successfully overcome only when there is something better (namely, Newtonian concepts) is available to replace them. Overall, it is envisaged that collaborative learning can help overcome alternative conceptions when done in a correct way.

### 2.3.3 ALTERNATIVE CONCEPTIONS ABOUT FORCE AND NEWTON'S LAWS

In the experience of the researcher there a number of alternative conceptions in mechanics that relate to force, Newton's laws, projectile motion, work and energy. These alternative conceptions are briefly discussed in the following paragraphs.

The most common alternative conception is the one which dates back for ages; it is the idea that sustaining motion requires a continued force (Bueche, 1986:57). Prior to Newton's time, everyone assumed that a force was needed to keep an object moving. For example, if one slides a book across a table, it soon stops. To keep it moving, one needs to continue to push on it. Indeed, it is nearly obvious that this observation although correct, does not apply to objects that have zero resultant force acting on them (Bueche, 1986:57). Learners need to view physics as a system of thinking about the world rather than information that can be dumped into their brain without evaluating its consistency with their belief systems (Giancoli, 2000).

The study by Tao (1997:1) reveals that Force and Motion Microworld (FMM) "may be offered as a supplement or alternative to other instructional tools for facilitating students' understanding in force and motion". The study by Eryilmaz (2002) on the effects of conceptual assignments and conceptual change discussions of students' achievement and misconceptions about force and

motion reveals that the conceptual change discussion is significantly effective in improving students' achievement in force and motion. With regard to the study by Eryilmaz (2002), the teachers administered the Force Misconception and Force Achievement Tests to their physics students. The same tests were used as post-tests. The statistical results showed that the conceptual change discussion was an effective means of reducing the number of alternative conceptions students held about force and motion (Eryilmaz, 2002).

### *Alternative Conceptions about Newton's Third Law*

The word force is used to describe the interaction between two objects. By way of definition, force is a push or pull upon an object resulting from the object's interaction with another object (Giancoli, 2000). When two objects interact, they exert forces on each other. Newton's third law states that these forces are equal in magnitude and opposite in direction. If object A exerts a force on object B, object B exerts a force on A that is equal in magnitude and opposite in direction. Thus, the forces always occur in pairs. It is common to refer to one force in the pair as an action and another as a reaction. According to Tipler (1997: 89) this terminology is unfortunate because it sounds like one force 'reacts' to the other, which is not true. Tipler (1997:89) further posits that "both forces occur simultaneously. Either can be called the action and the other the reaction."

In support of Tipler, Brown and Clement (1987) also state that "it makes no difference which force you call the action and which the reaction, because they occur at exactly the same time." The action does not 'cause' the reaction. Action and reaction coexist. You cannot have one without the other. Brown and Clement (1987) further maintain that in a way these forces are like debt and credit. One is impossible without the other; they are equal but of opposite signs, and different objects apply them. Giancoli (2000) also posits that to avoid confusion, it is very important to remember that the action force and the reaction force are acting on different objects. Roger (1993:12) also avers that this law is



often misinterpreted as meaning that the two forces cancel each other out because they are of equal strength and act in opposite directions. There is, in fact no possibility of this, because the two forces each act on different bodies. Examples of action and reaction forces are given in Table 2.1 below (Bueche, 1986:59):

**Table 2.1** The Examples of Action and Reaction Forces

<b>Situation</b>	<b>Action Force</b>	<b>Reaction Force</b>
Club hits golf ball	Club's force on ball	Ball's force on club
Girl slaps boy	Hand's force on face	Face's force on hand
Satellite orbits earth	Earth's pull on satellite	Satellite's pull on earth
Magnet attracts nail	Pull of magnet on nail	Pull of nail on magnet
Boy jumps up from the floor.	Foot pushes on floor	Floor pushes on foot

According to Brown and Clement (1987:28), column two in Table 2.1 (Action Force) can be referred to as reaction force and in the same way column three can be referred to as action force. The forces occur simultaneously, in opposite directions and act on different objects.

#### *Alternative Conceptions about Mass and Weight*

The findings of the study by Gonen (2008) reveal that student teachers have serious alternative conceptions about inertia, gravity, gravitational acceleration, gravitational force and weight concept. The aims of Gonen (2008:2) study “were considered under three headings, that is, (1) to elicit alternative conception that science and physics student teachers had about the terms, “inertial mass”, “gravitational mass”, “gravity” and “weight”; (2) to understand how prior learning affected their alternative conceptions, and whether teachers’ alternative conceptions affected their students’ learning; and (3) to determine the difference between science and physics student teachers’ understanding levels related to mass and gravity, and between their logical thinking ability levels and their attitudes toward physics lessons. The results of the study by Gonen (2008)

revealed that student teachers generally had positive attitudes toward physics lessons, and their logical thinking level was fairly good.

Learners also tend to confuse mass with weight and *vice versa*. Learners use these concepts as used in layman language and hence alternative conceptions in mechanics. Griffith (2007:64) maintains that weight is a familiar term often used interchangeably with mass in everyday language. Physicists make a distinction between mass and weight that is important to Newton's theory. Bueche (1986: 61) defines mass in terms of the 1-kg standard mass. Other masses are defined by comparison with this standard mass.

Tipler (1997:85) defines mass as an intrinsic property of an object that measures its resistance to acceleration. That is, the measure of the object's inertia. In the same way, Giancoli (1991) also defines mass as the measure of the inertia of a body, that is, the more mass a body has, the harder it is to change its state of rest or of motion. It is harder to start it moving from rest, or to stop it when it is moving, or to change its motion sideways out of a straight-line path. Mass is a scalar quantity, that is, it only includes magnitude, and its Systeme International (SI) unit is kilogram (kg). On the other hand, the weight of an object is the force with which gravity pulls on it. Roger (1993:13) defines weight of a body as the force acting on its mass due to the gravitational attraction of the earth. Weight is a vector quantity, that is, it includes magnitude and direction. The SI unit of weight is newton (N) plus direction. Thus, the mass of a body is the same everywhere whereas the weight of a body on the surface of the earth has a slight dependence on where it is, that is, its location, and would have considerably different values at other places in the Universe.

In this section, the literature on alternative conceptions in mechanics, particularly about force, Newton's third law, mass and weight has been presented. The origins of alternative conceptions and the ways to overcome them were also reviewed. Palmer (2010:2) reports that "research has shown that students often

appear to have multiple conceptions in science – they may apply one conception in one problem and a different conception in another related problem”. Alternative conceptions have their own origins that as well include physical science educators. Science learners usually confuse mass with weight. Schoon and Boone (1998:2) opine that “some alternative conceptions may represent greater barriers to learning than others”.

## 2.4 LEARNING THEORIES

This section reviewed the learning theories with an aim to finding ways of alleviating conceptual difficulties and alternative conceptions in mechanics for grade 12 physical science learners. Many researchers have developed a number of models and theories about learning and how learning is acquired. Pazos, Azpiazu, Silva and Rodriguez-Paton (2002, as cited by Alonso, Lopez, Manrique and Vines, 2005:221) define learning as the

acquisition of new mental schemata, knowledge, abilities, skills, etc, which can be used to solve problems potentially more successfully, furthering decision making on the basis of experience, which elevates ‘doing’ as a basis for achieving an effective understanding of knowledge.

Rumelhart and Norman (1978, as cited by Alonso, *et al*, 2005:221) state that learning is not a single activity; it includes at least three different stages: Accretion, restructuring, and tuning. They further describe the three different stages as follows:

*Accretion* is the insertion of knowledge into established structures. *Restructuring* is the formation of new conceptual structures suited to the new knowledge, and *tuning* involves making this knowledge efficient, that is, progressing from the unsure and anxious state of the learner to the serene and experienced skill of the expert.

Furthermore, Alonso, *et al*, 2005:221) maintain that

It is not enough to understand and learn a subject. When a subject has been learned, it should be used. It should be practised... If the principle is

understood but not automated, any attempt to apply it will end up in frustration.

In this regard, “learning does not stop at comprehension; the underlying fundamentals need to be completely automated...automaticity only comes with repeated practice” (Alonso, *et al*, 2005:221).

During learning, learners acquire levels of knowledge, which Bloom defined within a taxonomy of educational objectives (knowledge, comprehension, application, analysis, synthesis and evaluation), which is still widely accepted today (Bloom, 1956). These objectives describe several knowledge levels, intellectual capabilities, and skills that a learner can achieve through learning and which, briefly, are:

- Syntactic level – where the learner acquires the *knowledge and understands* its fundamentals and the underlying reasoning processes.
- Semantic level – learners are able to successfully tackle *analysis and synthesis* processes in new or complex situations. They have the ability to decide what method, knowledge, and instruments to use in each case. This knowledge is demonstrated by describing knowledge maps, decision tables, etc, of real problems.
- Pragmatic level – learners able to *apply* the knowledge acquired to solve particular problems and to *evaluate* the methods, processes, and tools to be used, which they can judge both qualitatively and quantitatively (Alonso, *et al*, 2005: 222).

This implies that learning is not complete or balanced if the knowledge levels are not catered for in the learning situation.

In support of the above-mentioned knowledge levels, Schulman (2002) also identifies a six-stage learning process: engagement and motivation, knowledge and understanding, performance and action, reflection and critique, judgement and design, and commitment and identity. Alonso, *et al*, (2005:222) describe this six-stage learning process as follows:

Learning begins with student engagement, which in turn leads to knowledge and understanding. Once a learner understands, he or she becomes capable of performance and action. Critical reflection on one's practice and understanding leads to higher-order thinking in the form of a capacity to exercise judgement in the face of uncertainty and to create designs in the presence of constraints and unpredictability. Finally, the exercise of judgement allows the learner to develop commitment. In commitment, he or she becomes capable of professing his or her understandings and his or her values, internalising those attributes and making them integral to his or her identity. These commitments, in turn, make new engagements possible and even necessary.

As the basis of this study, behaviourism, constructivism, together with other learning theories are discussed below for better understanding of how knowledge is constructed or gained.

An important corollary to behaviourist and constructivist theories is structured and unstructured learning respectively. It is important to establish a balance between both forms of learning. In order to establish this balance, students must develop through stages of competency that are prerequisites to problem solving (Reddy, Ankiewicz & Swardt, 2005:17). Alonso, et al (2005:218) describe pedagogical principles as "theories that govern good educational practice, and as far as e-learning is concerned, good educational or instructional practice is represented by the instructional technology." They further posit that "instructional design has evolved in combination mainly with the development of the three basic learning theories: Behaviourism, cognitivism and constructivism" (Reddy, Ankiewicz & Swardt, 2005:17). On top of these, there is another learning theory developed known as connectivism, which is related to learning with the use of technology.

#### 2.4.1 JEAN PIAGET (THEORY OF COGNITIVE DEVELOPMENT)

Jean Piaget made a contribution to our understanding of children's thinking at different stages. The stage of concrete operations occurs between age 5 to age 12. The stage of formal operations develops during adolescence. Pupils in the formal operational stage can consider combinations of variables, appreciate the need to control certain variables in experimentation and separate relevant from irrelevant factors in their testing procedures (Driver, 1983). The key idea in Piaget's learning theory is that the learner constructs knowledge and is actively seeking meaning. The context of learning is that interaction with the physical world is crucial. What the learner brings to the learning environment and developmental differences in reasoning affect science learning (Hassard & Dias, 2009). Hassard and Dias (2009) report that Piaget's theory focuses on the development of thinking patterns from birth to adulthood. To Piaget, learning is an active process, and is related to the individual's interaction with the environment. Intelligence is the human form of adaptation to the environment. Piaget, and other cognitive scientists theorise that structures grow and develop through a process of interaction with the environment.

According to Lawson and Renner (1975), both science educators, the most important idea in Piagetian theory is that mental structures are derived from the dynamic interaction of the organism and the environment by means of a process called self-regulation or equilibration. According to cognitive scientists, there are three additional factors that influence the development of mental structures: experiences with the environment, maturation, and the social environment (Hassard & Dias, 2009). They further state that experience with the environment is essential since the interaction with the environment is how new structures are made (Hassard & Dias, 2009). Students need more experiences with the environment; they also need to interact socially.

There are also two important factors in Piaget's learning theory. These are assimilation and accommodation. Assimilation is the integration of new information with existing cognitive structures (Hassard & Dias, 2009:281). According to Piaget, learners perceive objects or events in relation to their fit with their existing mental schema. Piaget's notion of schema could be defined as a model, outline, or pattern that we mentally construct to assist explaining or mediating perception (Hassard & Dias, 2009:281). As stated in section 2.3 that learners do not come to class with empty minds because they develop beliefs about the things that happen in their surroundings from the very earliest days of their lives. According to Hassard and Dias (2009:281) "Piaget suggested that assimilation is dependent on the existence of an internal structure so that the new information could be integrated".

To alleviate conceptual difficulties and alternative conceptions, science educators should plan their lessons and instructional units in relation to the extant knowledge of the students, increasing the likelihood that learners will be able to make sense of new ideas by assimilating them into their schemas (Hassard & Dias, 2009:281).

Assimilation of new ideas requires some degree of modification of the existing schema, a process Piaget termed accommodation. By way of a definition, "accommodation is the adjustment of mental structures to the particular characteristics of events or objects that one is thinking about" (Hassard & Dias, 2009:282). Hassard and Dias (2009:282) state that "Piaget theorised that in cognitive functioning, internal mental structures adjust to the unique properties of new objects and events".

#### 2.4.2 DAVID AUSUBEL'S THEORY OF LEARNING

In his theory of learning, Ausubel posited that “the most single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly” (Ausubel, 1968: ix). Ausubel distinguishes between rote and meaningful learning, where new knowledge is related by the learner to relevant existing concepts. This is also known as assimilation theory of meaningful learning. Ivie (1998) also reports that Ausubel's (1962) theory makes a distinction between rote and meaningful learning, which is important for teaching higher order thinking. According to Ivie (1998) rote learning occurs when the learner memorises information in an arbitrary fashion. The knowledge or information is stored in an isolated compartment and is not integrated into the person's larger cognitive structure. This is associated with the traditional approach to teaching and learning, which is said to have encouraged rote learning and memorisation. Ausubel (1962:215-216) further states that “rotely learned materials are discrete and isolated entities which have not been related to established concepts in the learner's cognitive structure”. Because rote learning is not anchored to existing concepts, it is more easily forgotten (Ivie, 1998).

Meaningful learning, on the other hand, is part and parcel of higher order thinking. By way of description, higher order thinking takes place when we grasp the interrelationship between two or more ideas, old and new (Ivie, 1998). Ausubel and Robinson (1969:46) contend that “a first prerequisite for meaningful learning is that the material presented to the learner be capable of being related in some ‘sensible’ fashion”. This suggests that the new information must be fitted into a larger pattern or whole. “Second, the learner must possess relevant ideas to which the new idea can be related or anchored” (Ausubel & Robinson, 1969:46). “Finally, the learner must actually attempt to relate, in some sensible way, the new ideas to those which he presently possesses” (Ausubel &



Robinson, 1969:46). Ivie (1998) posits that if any of these conditions is missing, the end result will be rote learning.

Novak (1998:11) concurs with Ausubel in summarising the relation between rote learning and meaningful learning as follows:

Either reception instruction or discovery approaches can be rote or very meaningful learning experiences. The rote-meaningful learning continuum is distinct from the reception-discovery continuum for instruction. School learning needs to help students move toward high levels of meaningful learning, especially in reception instruction that is the most common.

Ausubel (1963:15) also opines that the problem stems from the widespread confusion “between reception and discovery learning, and between rote and meaningful learning”. Reporting on this confusion, Ivie (1998) states that reception learning is not invariably rote; likewise, discovery learning is not always meaningful. Either one—reception learning or discovery learning—can be rote or meaningful. Everything depends upon how the knowledge is treated.

Ausubel and Robinson (1969) also contend that there is a place for practice or drill in teaching higher order thinking. They assert that “most integrated sets of ideas are not learned in a single presentation” (Ausubel & Robinson, 1969:131). In support of Ausubel and Robinson, Ivie (1998) also state that formal education is a slow, incremental process. Ivie (1998) further asserts that what is acquired one day provides the basis for what will be learned the next. Therefore, practice or drill is necessary in order to master most classroom learning. Ausubel (1963) cautions us that it is a grave error to assume “all structured practice (drill) is necessarily rote, that unstructured (incidental) practice is maximally effective for school learning tasks”. Drill is never outdated; however, everything depends upon how drill is used, rotely or meaningfully.

### 2.4.3 JEROME BRUNER

Jerome Bruner is credited as the principal originator of cognitive and constructivist psychology, and also of having had a profound effect on educational theory and practice. Bruner's most memorial contribution to science education was his following conviction: "Any subject can be taught in some intellectual honest fashion to any child at any stage of development" (Mintzes & Wandersee, 1998:37). It is therefore not the age of the student that determines readiness to learn topics such as algebra, but instead the cognitive background of the students and how the opportunity for learning has been structured.

According to Bruner, the mystery of skills can be transferred to even more powerful skills and other domains. Bruner places linguistics in education as a teaching tool, as symbolic representation and as an instrument of thought. He further developed inductive reasoning and problem solving that provided the foundation for discovery learning, as the preferred instructional approach, which was subsequently related to constructivism. The learner learns best by discovering; the learner is a problem solver who interacts with the environment testing hypotheses and developing generalisations (Bruner, 1986). According to Bruner, discovery learning has three (3) stages namely, active stage, where the learner has to be able to touch, feel, move, etc, the object; visualisation, where the learner uses images, drawings and graphics to represent the new concepts; and symbolic stage, which involves symbols and language. Therefore, Bruner opines that the process is more important than memorising facts. Bruner (1986) further felt that the goal of education should be intellectual development, and that the science curriculum should foster the development of problem-solving skills through enquiry and discovery.

Bruner (1986) also believed that knowing was a process rather than the accumulated wisdom of science as presented in textbooks. To learn science concepts and to solve problems, students should be presented with perplexing

situations. Hassard and Dias (2009) posit that providing discrepant events and opportunities to explore interesting phenomena fuels the learner's intrinsic motivation to figure things out. This simple notion provides the framework for creating discovery-learning activities. Bruner's instructional theory has four components (1986): Curiosity and Uncertainty; Structure of Knowledge; Sequencing; and Motivation.

With regard to curiosity and uncertainty, Bruner (1986) felt that experiences should be designed to help the student to be willing and able to learn. He called this the predisposition toward learning. Bruner (1986) also believed that the desire to learn and to undertake problem solving could be activated by devising problem activities in which students would explore alternative solutions.

Regarding structure and knowledge, Bruner (1986:41) expressed it by saying that the curriculum specialists and teachers "must specify the ways in which a body of knowledge should be structured so that it can be most readily grasped by the learner." Accordingly, Hassard and Dias (2009) observe that this idea became one of the important notions ascribed to Bruner. Bruner (1986:44) further explained it this way: "Any idea or problem or body of knowledge can be presented in a form simple enough so that any particular learner can understand it in a recognisable form." According to Bruner (1986) any domain of knowledge (physics, chemistry, biology, earth science) or problem or concept within that domain (law of gravitation, atomic structure, homeostasis, earthquake waves) can be represented in three ways or modes: by a set of actions, by a set of images or graphics that stand for the concept; and by a set of symbolic or logical statements.

With regard to sequencing, Bruner (1986) believed that instruction should lead the learner through the content in order to increase the student's ability to "grasp, transform and transfer" what is learned. According to Bruner (1986) sequencing

should move from enactive (hands-on, concrete), to iconic (visual), to symbolic (description in words or mathematical symbols).

Bruner's fourth principle deals with motivation. This last aspect of Bruner's theory is that the nature and pacing of rewards and punishments should be specified (1986). Bruner (1986) further suggests that movement from extrinsic rewards, such teacher's praise, toward intrinsic rewards inherent in solving problems or understanding the concepts is desirable. To Bruner, learning depends upon knowledge of results when it can be used for correction. Bruner also mentions that feedback to the learner is critical to the development of knowledge.

#### 2.4.4 ROBERT GAGNE`

Robert Gagne` developed ideas about conditions of learning and believed that effective instruction should go beyond traditional learning theories. He supported cumulative teaching from simple to complex skills (Killpatrick, 2001). He further identified two factors in his model for conditions of learning which could make a real difference in instruction:

- a. categories of human capabilities to be established for attainment of learning outcomes:
  - (i) intellectual skills, e.g. addition and subtraction;
  - (ii) cognitive strategies, which include inductive and deductive reasoning, e.g. exploring the action of a magnet;
  - (iii) verbal information, e.g. learning the elements of the Periodic Table;
  - (iv) motor skills, e.g. measuring with the vernier callipers; and
  - (v) attitudes, e.g. how one feels about the nature of science.
- b. Events Instruction: Gagne` (1977) describes instruction as events of learning external to the learner which are designed to promote

learning. The sequence of nine instructional events and the corresponding learning processes that guide the design of instruction follows:

- (i) gain attention: distribute course outline and training agenda to pique the learner's interest in the subject;
- (ii) inform learner of objective: let the learner know what they will be learning and discuss the student-centred learning objectives;
- (iii) recall prior knowledge: get the learners to think about what they already know, e.g. students complete a pre-test available at an online site, prior the intervention;
- (iv) present material: teach the topic, e.g. students to prior reading on the procedure of a practical;
- (v) provide guided learning: help the learners follow along as the topic is presented, e.g. provide text or images, e.g. picture posters of steps involved in the practical procedure, to enhance the encoding of material;
- (vi) elicit information: ask learners to do what they have been taught, e.g. in a three hour practical session to practice skills;
- (vii) provide feedback: inform learners of their performance;
- (viii) assess performance: evaluate learners on their knowledge of the topic, e.g. assess skills during hands-on competency sessions; and
- (ix) enhance retention and transfer: aid learners in remembering and applying new skills.

Central to Gagne's theory on conditions of learning is that instruction must be designed specially in the context of the learners' needs. Instruction should be designed to include a variety of instructional methods in order to meet the needs of different learners (Killpatrick, 2001). Three interventions are used in this study of which blended approach is one of them. In line with Gagne's learning theory, the blended approach is an approach that mixes different learning delivery modes (Singh & Reed, 2001) to meet the needs of different learners.

#### 2.4.5 JOSEPH NOVAK

Novak realised that there can be science of science education, and indeed, even a science education. His challenge was to help create new principles and theories that could lead to the science of education (Novak, 1998). Novak has developed a theory of education to guide research and instruction from research focused on human learning, educational studies and knowledge creation and representation (Novak, 1984). Novak suggested that Ausubel's assimilation theory of meaningful learning, which stresses the importance of prior knowledge in learning new concepts, offered science educators a more useful and valid model of learning than the Piagetian stage-dependent model. Novak therefore supported a model of cognitive development that was not stage dependent, but rather dependent on the framework of specific concepts and integrations between these concepts acquired during the lifespan of an individual (Driver, 1983).

Novak invented the "concept map" (Novak, 1998). Mintzes, Wandersee and Novak (2001) describe a concept map, which has its origin in constructivism where learners actively construct knowledge, as an instructional process or an assessment device to represent students' knowledge and understanding of complex concepts and how they relate. This technique helps students to organise subject matter and diagnose conceptual errors and faulty reasoning when a student is asked to construct a map of a certain area of knowledge (Coetzee, 2008). Changes in learners' cognitive structures, missing concepts and alternative conceptions are identified with relative ease (Novak, 1998; Roth, 1990). Novak (1984) points out that meaningful learning involves the assumption of new concepts and propositions into existing cognitive structures. Therefore in teaching and learning, it is important to identify what the learners already know.

#### 2.4.6 ERNST VON GLASERSFELD

In a view of Ernst von Glasersfeld's contribution to science education, Tobin (2007) suggested that Glasersfeld's "subversive ideas" impacted the field of science teaching, resulting in new ways of thinking about teaching and learning, curriculum, and science teacher preparation. To von Glasersfeld, those who hold on to the idea that conceptual ideas represent an independent, objective reality represent the traditional theory of knowledge. Von Glasersfeld coined the term "radical constructivism" to imply "going to the roots," or "uncompromising" (von Glasersfeld, 2005). Radical constructivism as related by von Glasersfeld helped many educators to appreciate that thinking, conceptualising, and language are developed from experience (Hassard & Dias, 2009). Based on the work by physicist and educator Dykstra, Jr., hereunder the two instructional approaches (realist approach and radical constructivism) are compared to help understand radical constructivism.

The realist approach (traditional science teaching) to teaching is seen when a concept is presented as if students can receive it in the same form as the teacher who communicated the knowledge (Dykstra Jr. 2005). The methodology in the realist approach boils down to "inform, verify, and practice" and this has been a method used for a long time. This approach assumes that ideas are out there and we can pass them on to students by making the content available via the spoken and written word. Science textbooks have been based on the idea of outlining concepts that are to be read and "taught" to students. Dykstra Jr. reports that instructional intervention using the realist approach to teaching shows very little change, and very little understanding of force and motion.

Radical constructivism is an alternative paradigm for teaching science. This theory is based on two principles (Dykstra Jr., 2005):

- Knowledge is not passively received but actively built by the learner.

- The function of cognition is adaptive (Piaget's concepts) and serves to organise our experiences.

Hassard and Dias (2009:284) state that "the purpose of teaching that embodies von Glasersfeld's theory is to help students develop new understandings as a result of experience in the classroom." Dykstra Jr. (2005) further states that instead of being content-driven, the radical constructivist approach to teaching is student-understanding driven. In this radical constructivist approach to teaching, knowledge is divided into two types, that is, experiential knowledge and explanatory knowledge. These two types of knowledge cannot be given to someone else. Knowledge gained through experience will possess qualities as varied as the learners and their manner of engagement, and thus, these experiences cannot be transmitted directly by language. The learner must experience and the teacher must skilfully mediate experience (Hassard & Dias, 2009). Furthermore, (Quale, 2007) posits that explanatory knowledge is the meaning generated by the student, not declarative statements. Explanatory knowledge can be cognitive (science conceptions) or non-cognitive (affective or emotive knowledge). Quale (2007) further opines that explanatory knowledge of the concepts exist only in the mind of each student in the class. Learning is constructed by the student as a mental entity. As teachers the "transmission" or communication of knowledge via lecture, lab, or any other method is at best offered in a manner that facilitates the learners' understanding (Quale, 2007).

Hassard and Dias (2009), report that Piaget and von Glasersfeld suggested that the desire for equilibration motivates student engagement in learning activities. Teaching based on constructivism theory uses experience, trial and error, and reasoning to help students understand science. Quale (2007:57) further states that

the student understandings that fall short of the best conception that "science" has to offer are considered naïve conceptions rather than misconceptions (alternative conceptions) because these are the



understandings that students have built up through their experiences. It is therefore not the role of the teacher to “correct” these conceptions, but to provide experiences through which the student may revise their conception.

Constructivists believe that school science should provide access to hands-on experiences, and opportunity to evaluate and justify science knowledge.

#### 2.4.7 JOHN DEWEY

Hassard and Dias (2009) report that Dewey believes that learning is embedded in experiences when the student interacts with the environment, which is when humans work to deal with the tensions between themselves and their surroundings. They further report that Dewey believes that learning is natural, not process limited. To Dewey, the learner is active, and within science education they would be experimenting, analysing an environment and using tools like telescopes and hand lenses to glimpse the world they are exploring. To learn, Dewey insists that we cannot ‘give’ ideas directly to students; rather they have to be presented indirectly (Hassard & Dias, 2009). It is further reported that Dewey saw that ‘informal’ learning was significant in that it would shed light on the shortcomings of ‘formal’ and ‘intentional instruction’ (Fishman & McCarthy, 1998:22).

According to Dewey’s learning theory, a learner is viewed as active and participates in the context of educative experiences or projects that have a structure, flow and energy (Hassard & Dias, 2009).

Dewey also believes in experience and ideas-based teaching. According to Dewey’s notion of experience, science teachers should provide students with transformative experiences that are valuable in them and valuable in their potential to lead to other worthwhile experiences (Dewey, 1934, as cited in

Wong, Pugh & the Dewey Ideas Group at Michigan State University, 2001). Hassard and Dias (2009) also posit that teachers have to set up experiences that create anticipation on the part of students. One way to do that is to engage students in “big ideas”. Hassard and Dias (2009) report that Wong and Pugh identify several characteristics of Dewey’s “big ideas”.

- Ideas need to be connected to the subject matter of science. Students need to anticipate the emotional qualities of an idea.
- Ideas inspire action; only in action do ideas have meaning and value.
- Ideas have distinct emotional quality. Feelings are connected to anticipation – the seeking of some future experience connected to the ideas. Students involved in experiences with emotional content are motivated to experience the idea (Dewey, 1934, as cited in Wong, Pugh & the Dewey Ideas Group at Michigan State University (2001)).

Hassard and Dias (2009) also report that Wong and Pugh offer an alternative, and that is to organise science teaching around ideas rather than science concepts. Science concepts, as they point out, are the ways that people represent or think about the world (Dewey, 1934, as cited in Wong, Pugh & the Dewey Ideas Group at Michigan State University (2001)). By way of definition, an idea is something that seizes the students and transforms them (Hassard & Dias, 2009). As Wong and Pugh point out, the goal of ideas-based teaching is to help students be taken by an idea and to live with it, to be with it in their world (Dewey, 1934, as cited in Wong, Pugh & the Dewey Ideas Group at Michigan State University (2001)). Ideas-based teaching starts with an examination of the concepts that a teacher would want to use to organise instruction (Hassard & Dias, 2009). They further state that it is important that the teacher identifies the “big ideas” in the domain that subsumes the science concepts.

#### 2.4.8 LEV VYGOTSKY

Vygotsky (1986) promotes the idea that all higher-level learning take place on a “social plane.” Listening and talking, reading and writing are essential. Hassard and Dias (2009) report that to Vygotsky and his proponents, the social context and language discourse are paramount to human learning. Teachers embodying this view would integrate personal and social perspectives on learning and emphasise the role of dialogue in helping students construct science knowledge.

Vygotsky (1986) further distinguishes between two different forms of experience which give rise to two interrelated concepts: the “scientific” and the “spontaneous.” According to Vygotsky, scientific concepts develop in highly structured and specialised activities in school classrooms. Spontaneous concepts, on the other hand, originate from the student’s own reflections on everyday experience. Vygotsky emphasises the development of scientific concepts in the school environment and neglects the spontaneous concepts that students bring to school. Hassard and Dias (2009) report that Piaget had reached the same conclusions, having distinguished between spontaneous and non-spontaneous concepts. To Piaget, teachers should incorporate students’ spontaneous concepts into teaching.

The implication here for science teachers is to make science knowledge available on the social plane, and to provide opportunities for students to make sense of science via thoughtful discussion with their classmates, teachers, even parents, siblings, and other children. According to this view, social interaction takes on a major role in student learning (Lemke, 1994). One of the key implications of the sociocultural perspective on student learning is collaboration within groups in a classroom, as well as within larger networks using computers. Collaborative learning (also known as cooperative learning) is a practical application of sociocultural theory (Hassard & Dias, 2009). With regard to implication for teaching, Hassard and Dias (2009) point out that most teaching

takes place in groups, and it is therefore imperative that science teachers closely examine the results of research on small group learning. Students interact with each other, and it is important to know how this interaction contributes to student learning.

When properly understood by science educators, these learning theories can also assist in dealing with conceptual difficulties and alternative conceptions. As stated in section 2.3, learners come to class with a set of beliefs which they are unwilling (or not easily willing) to discard despite evidence to the contrary (Oliver, 1992). It was also stated that learners come to physical science class with already strongly held ideas which may differ from the theories the educator may wish to develop. In this regard, physical science educators should clearly understand Piaget's theories of assimilation and accommodation (Piaget, 1986) to help alleviate the alternative conceptions in mechanics. Assimilation (the theory of meaningful learning) stresses the importance of prior knowledge in learning new concepts.

Ausubel (1968) argues that the most single factor influencing learning is what the learner already knows. Physical science educators should ascertain this and teach learners accordingly. One way to do this is to begin by doing the baseline assessment (or a pre-test). This helps to identify the alternative conceptions and areas of conceptual difficulties. Learners will then be able to relate the new knowledge to relevant existing concepts in their mental structures. This is known as the assimilation theory of meaningful learning (Ausubel, 1968). The material presented by educators to learners should be capable of being related to some 'sensible' fashion as a first prerequisite for meaningful learning (Ausubel & Robinson, 1969:46). Bruner (1986) prefers discovery learning as the best instructional approach for problem solving. Bruner believed that learners learn best by discovering. The learner is the problem solver who interacts with the environment testing hypothesis and developing generalisations (Bruner, 1986). Furthermore, Bruner (1986) believed that knowing was a process rather than the accumulated wisdom of science as presented in textbooks. With regard to

conceptual difficulties, Hassard and Dias (2009) asserted that to learn science concepts and to solve problems, learners should be presented with perplexing situations. Hassard and Dias (2009) further maintain that providing discrepant events and opportunities to explore interesting phenomena fuels the learner's intrinsic motivation.

Conceptual difficulties and alternative conceptions can also be alleviated through the use of Novak learning theory. Novak (2001) believed that concept map (where learners actively construct knowledge) helps learners to organise subject matter and diagnose conceptual errors and faulty reasoning.

Gagne supported cumulative teaching from simple to complex (Killpatrick, 2001). Gagne argues that instruction should be designed specially in the context of the learner's needs. Furthermore, Gagne believed that instruction should be designed to include a variety of instructional methods in order to meet the needs of different learners (Killpatrick, 2001). This belief is in line with the blended approach, that is mixing different learning delivery modes.

#### 2.4.9 BEHAVIOURIST THEORY OF LEARNING

Mda and Mathata (2000:32) state that the philosophy of behaviourism has a strong psychological bias, focusing on external human behaviour, which can be observed. According to Morrison (1993:63-64) the basic behaviourist principles are:

- Observable behaviours are important. Human behaviour is overt, observable and measurable. The formulation of specific objectives (or outcomes) that describe the ideal behaviour is an integral feature of behaviourism.
- The environment is important. Observable, measurable behaviour is dependent on stimuli from the environment.

Thus, with reference to South Africa, Mda and Mathata (2000:32) aver that: “OBE is based on strong behaviourist assumptions as evidenced by the way Spady defines outcomes”.

More specifically, Spady (1994:2) defines outcomes as “clear learning results that we want students to demonstrate at the end of significant learning”. He goes on to say that outcomes are what learners can actually do with what they know and have learned. On its part, the South African Qualifications Authority (SAQA) formulated critical and developmental outcomes for education and training in South Africa which were subsequently interpreted as specific outcomes for the eight learning areas in the General Education and Training (GET) band (grades 0 – 9). SAQA further provided guidelines for the organisation of education and training and, in doing so, formulated standards that included assessment criteria. The use of active verbs in formulating learning outcome was stressed. These active verbs relate to facets of observable behaviour such as collect, identify, analyse, demonstrate, etc. The document uses very few concepts such as wonder, aspire, visualise, reflect, meditate, imagine, etc., because such concepts indicate invisible and inherent learning behaviour, which behaviourism does not provide for (Steyn & Wilkinson, 1998:204).

An outcome is an achievement within a specific context (Oliver, 1997:17). In curriculum 2005, a set of range statements was provided in an attempt to describe the context or situation in which the specified outcomes were to be demonstrated. Range statements were defined as indicators of the scope, depth, level of complexity, and also the critical areas of content, processes and context which the learner needed to engage with in order to reach an acceptable level of achievement (Republic of South Africa, 1997:17).

Mda and Mothata (2000:32) conclude by saying that OBE, with visible, measurable and specifically formulated outcomes, has strong roots in behaviourism.

The theory of behaviourism concentrates on the study of overt behaviours that can be observed and measured. It views the mind as a “black box” in the sense that response to stimulus can be observed quantitatively, totally ignoring the possibility of thought processes occurring in the mind (Good & Brophy, 1990). Saettler (1990) identified the impact of behaviourism on educational technology with areas such as the programmed instruction movement, computer-assisted learning, etc. The behaviourist approach had limitations as regards the understanding of learning. For example, behaviourism was unable to explain some social behaviour. People could imitate behaviour that they had not reinforced. An individual could model behaviour by observing the behaviour of another person (Bandura, 1977).

### **Behaviourist Theory and Science Education**

In the behaviourist approach to learning, the emphasis is on controlling those behaviours of the learner that can be observed and measured and could be best served through the following instructional strategies: direct instruction, whole class teaching, lecture and demonstrations (Reddy, Ankiewicz & Swardt, 2005:18). The direct instructional strategy is widely applicable and can be used to teach concepts, factual knowledge and basic skills (Gunter, Estes & Schawb, 1995:60, as cited by Reddy, et al, 2005:18). This strategy places the teacher at the centre of instruction. When the direct instructional approach is used the teacher assumes major responsibility for structuring the content or skills, providing opportunities for practice and giving feedback (Eggen & Kauchak, 1996:181).

In science education, like in most other learning fields of study, there is a body of content (factual) knowledge that needs to be learnt, and there are basic practical skills and techniques that have to be mastered before these could be applied meaningfully (Dugger, 1997). This means that the teacher teaches, instructs and demonstrates and learners model themselves on the teacher, by learning the theory and applying the skills (Down, 1996:231).

Reddy, *et al*, (2005:19) state that every teacher, of every subject/learning area, at every level of schooling has some learning outcomes related to the acquisition of factual knowledge and the mastery of basic skills before the learner can move to higher levels of thinking and learning. Reddy, *et al* (2005:19) posits that certain types of outcomes require that practice and feedback receive particular attention. Outcomes in the psychomotor domain (practical, procedural knowledge), in particular, necessitate drill and practice, (e.g. practical skills in science subjects) whilst outcomes in the knowledge domain (conceptual knowledge) may require information to be committed to memory (Royer, 1996, in Johnson, 1997).

Demonstrations by the teacher (an associated strategy of the behaviourist instructional approach) are important for learning (Gagne` & Biggs, 1972). This strategy is based on the idea that skills (e.g. apparatus and equipment skills in science) are acquired as a result of learners observing how things are done, then practising the skills for themselves under the supervision of the teacher.

Whilst practical problem solving is central to science education, Down (1996) states that there are numerous things that need to be learnt in the transmission mode of teaching that need not involve problem solving methods. Notwithstanding the value of direct instruction in science, the very nature of science education demands that learners engage in processes of creative and critical thinking, decision making, problem solving and design (Reddy, *et al*, 2005:19). Furthermore, Reddy, *et al*, (2005:19) posit that instructional practices



that lead to the enhancement of intellectual skills development could depend on an understanding of constructivist learning theory.

#### 2.4.10 CONSTRUCTIVIST THEORY OF LEARNING

Constructivist theory maintains that learners construct or at least interpret their own reality based upon their perception of experiences. Therefore, an individual's knowledge is a function of his or her prior experiences, mental structures, and beliefs that are used to interpret objects and events (Jonassen, 1991). Alonso, et al (2005) further state that one of the most useful tools for a constructivist designer is hypertext and hypermedia because it allows for a branched design rather than a linear format of instruction.

Furthermore, Alonso, et al (2005:219) opines that constructivism builds upon behaviourism and cognitivism in the sense that it accepts multiple perspectives and maintains that learning is a personal interpretation of the world. Cognitive theory is briefly described as a theory that views learning as involving the acquisition, or reorganisation, of the cognitive structures through which humans process and store information (Alonso, et al, 2005). Thus, the mental processes transform the information received through the eyes and ears into knowledge and skills within the human memory. The new knowledge and skills are then stored in this memory.

Imenda (2005b:331) emphasizes the students' responsibility in the constructivist learning approach:

For students to benefit from constructivist instructional approaches, it is important that they undergo a paradigm shift which necessitates that they see it as their responsibility to invest the necessary intellectual commitment to learning. This entails that they do things which were traditionally the preserve of the teacher – such as researching information and organising it for easy learning.

Learners have a tendency to relax and think that it is the responsibility of the teacher to research, organise and explain all information to them. This habit needs to be discouraged by giving learners projects and assignments, as a way of learner involvement.

A constructivist perspective on learning (e.g. Piaget, 1970; Skemp, 1979) assumes that concepts are not taken directly from experience, but that a person's ability to learn from what he learns from experience depends on the quality of the ideas that he is able to bring to that experience. Knowledge does not simply arise from experience. Rather, it arises from the interaction between experience and our current knowledge structures (Oliver, 1992:195).

The student is therefore not seen as passively receiving knowledge from the environment; it is not possible that knowledge can be transferred ready-made and intact from one person to another. The child is an active participant in the construction of his/her own knowledge. This construction activity involves the interaction of a child's existing ideas and new ideas, that is, new ideas are interpreted and understood in the light of that child's own current knowledge, built up out of his/her previous experience. Children do not only interpret knowledge, but they organise and structure this knowledge into large units of interrelated concepts (Oliver, 1992:196).

Mintzes *et al* (1998, as cited by Coetzee, 2008) divide the constructivist camp as follows:

- **Radical constructivists** reject entirely the notion that scientific knowledge can be tested against an external reality.
- **Social constructivists** contend that reality itself is simply a product of social negotiation.
- **Human constructivists** believe that human beings are meaning-makers and that the goal of education is to construct shared

meanings facilitated through the active intervention of well-prepared teachers. Meaningful learning occurs through extended periods of interaction with objects, events and other people. Divergent and creative thinking are supported and rewarded.

To the constructivist, learning is not, as for the behaviourist, a matter of adding, or stockpiling new concepts to existing ones. Rather, learning leads to changes in learners' schemata. Because knowledge cannot be transferred ready-made, to support the child to construct his own, discussion, communication, reflection and negotiation are essential components of a constructivist approach to teaching (Oliver, 1992). From a constructivist perspective, misconceptions are crucially important to learning and teaching because they form part of a learner's conceptual structure that will interact with new concepts, and influence new learning, mostly in a negative way, because misconceptions generate errors (Oliver, 1992).

#### **2.4.10.1 Constructivist Theory and Science Education**

It is popularly claimed that learning is an active process of knowledge construction on the part of the learner. This has contributed to the burgeoning popularity of constructivism as an instructional approach to learning. The popular view is that constructivism is synonymous with approaches to teaching that are progressive and learner centred and is a 'welcome antidote to traditional approaches' (O'Loughlin, 1992:336). McCormick (1997:148) states that constructivism focuses upon individuals building up representations of their knowledge, which is then tested against experience.

Arising from the constructivist instructional approach are various sub-approaches and concomitant instructional strategies. These sub-approaches include cooperative learning, discovery learning, enquiry and experiential learning. Instructional strategies associated with cooperative learning, for example are,

group work, discussion, debate and role play (Wheatly, 1991:10; Johnson, 1997; Banks, 1996).

Two perspectives representing constructivist theories of learning (which are relevant to learning and instruction in science education) are radical constructivism and social constructivism (Reddy, et al, 2005). According, Reddy, et al (2005) further state that the view of knowledge suggested by radical constructivism is that human beings are from birth engaged in the process of adaptation of knowledge. According to Zietsman (1996), human knowledge does not consist of real, true facts, but is viewed as knowledge that is viable to the individual, in making sense of the world that he/she lives in. Arising out of the radical constructivism approach to learning is the question of reflection and choice on the part of learners (hence the freedom for alternative conceptions) implying that any person can be an autonomous learner (Zietsman, 1991). However, this does not suggest that learners should be left to their own devices, since they have the potential to perform on their own, but radical constructivism suggests that teachers create situations in which learners could develop their innate drive towards acting independently (Candy, 1991). In this way, radical constructivism as an approach to learning has some important implications for learning science since each learner needs to be provided the opportunity to experience knowledge construction through the processes of creative and critical thinking, decision making, problem solving and design on an individual basis (Reddy, et al, 2005).

On the other hand, social constructivists see learning as a process of 'enculturization', whereby learners are induced into the cultural practices of the societies they live in. From a social constructivist perspective, the role of the teacher is that of mediating between learners' 'personal meaning' and the culturally established meanings of wider society (Cobb, 1994). This implies that the learner appropriates meaning from the social and the cultural environment (Magadla, 1996) for meaningful learning to take place. In support of this,

Ellsworth (1989; cited by O'Loughlin, 1992) states that all learners possess multiple frames of reference with which to construct knowledge, by virtue of their ethnic background, race, gender, language, as well as religious, cultural and political identities.

The nature of scientific activities lends itself amply to learners interacting with each other in a co-operative learning environment. Social constructivist theories of learning therefore have important implications for learning and instruction in science. Ankiewicz, Van Rensburg & Myburgh, 2001:3) posit that the thinking skills fundamental to science are creative and critical thinking, decision making and designing, leading to problem solving. Learning and instruction that characterize these skills flow naturally from constructivist theory of learning. However, science factual knowledge and other skills are best acquired in the behaviourist approach. Therefore, behaviourism is also appropriate in the context of science education.

Driver (1983) states that scientific theories are not deduced from data but are constructions of the human intellect. As Einstein and Infeld earlier observed:

Science is not just a collection of laws, a catalogue of unrelated facts. It is a creation of human mind, with its freely invented ideas and concepts. Physical theories try to form a picture of reality and to establish its connection with the wide world of sense impressions... with the help of physical theories we try to find our way through the maze of observed facts, to order and understand the world of our sense impressions. We want the observed facts to follow logically from our concepts of reality. Without the belief that it is possible grasp the reality with our theoretical constructions, without the belief in the inner harmony of the world, there could be no science (Einstein and Infeld, 1938:310, 312).

The constructivism draws on the developmental work of Piaget. As learning in science began to be viewed as an individual process of concept development

carried out in each student's mind a need for a different view of learning and knowing became necessary and constructivism began to be used in the science education literature to describe and explain learning (Wessel, 1999). Glasersfeld (1989) describes understanding as a matter of fit rather than match; a matter of actively building up rather than passively receiving.

Geer and Rudge (2002) describe constructivism as a theory of learning where students construct knowledge in the process of learning through social interaction and active participation with phenomena, as they develop shared-meanings of phenomena. Gray (1997) in his report summarises the constructivist teaching sequence by referring to four principles:

- (i) learning depends on what one already knows;
- (ii) new ideas occurs as one adapts and changes old ideas;
- (iii) learning involves inventing ideas rather than mechanically accumulating facts;
- (iv) meaningful learning occurs through rethinking old ideas and coming to new conclusions because of conflicts with the old ideas in the light of the new evidence.

#### **2.4.10.2 The Constructivist Classroom**

Coetzee (2008:97) outlines the features of a constructivist classroom and states that they include the following:

- A constructivist classroom is highly organized and structured. "Structure is one of the conditions of freedom ... there can be no freedom without some elements of constraint" (Sheridan, 1993:116; as quoted by Gray, 1997). Students are given a lot of choices to negotiate themes within the range of the prescribed curriculum (Gray, 1997).

- Multiple discrepant events and instructional methods are used to accommodate the diverse learners (Nussbaum, 1985, as cited by Wessel, 1999).
- Learner-centred active instruction and interactive engagement lead to conceptual change (Gray, 1997; Von Glasersfeld, 1989).
- The educator provides learners with experience that allow them to hypothesize, predict, manipulate objects, pose questions, research, investigate, imagine, invent, reason (Gray, 1997).
- Learners have opportunities to explore their own ways of thinking about the phenomena under discussion (Roth, 1990:155).
- Explain complex scientific concepts by means of everyday analogies. Unfortunately analogies may cause confusion and alternative conceptions if not chosen effectively and with care (Glynn, Duit & Thiele, 1995). They recommend several analogies for students to focus on the target concept from several perspectives.
- Students' ideas are articulated, tested through experimentation and conversions considered between their lives and concepts being studied (Julyan & Duckworth, 1996, as cited by Wessel, 1999).
- A non-threatening and supportive atmosphere is prevalent in the classroom where students feel free to express their ways of thinking (Mintzez, et al, 1998:330; Wessel, 1999).

In all the above, the teacher plays a key role in, ensuring that the classroom has all the above-mentioned features. Learners need to be guided since they cannot “develop scientific conversions by themselves; rather, they must be constructed with assistance from teachers who are part of the scientific community” (Driver, 1999; as cited by Coetzee, 2008:98). For their part, educators have to also undergo their own conceptual change about teaching and student learning.

### **2.4.10.3 The Constructivist Teacher**

The ability, to interpret classroom activity critically, to translate knowledge, wisdom and experience into a form of communication that is compelling and interesting, to identify and solve problems regarding teaching practice and to make thoughtful or reflective instructional and classroom management decisions that are conducive to learning, are well characteristics of expert educators (Zehm & Kottler, 1993; Parsons & Brown, 2002; Zeichner & Liston, 1996; Pasch, Sparks-Langer, Gardner, Stark & Moody, 1991; Smith, 1987)

Furthermore, Coetzee (2008:99) also outlines the features of a constructivist teacher as follows:

- Incorporates ongoing creative ways to set questions, group discussions, experiments and demonstrations that require students to rethink their ideas without unnecessarily emphasizing their wrong ideas (Mintzes, et al, 1998:330);
- Empowers students by operating as a facilitator (Gray, 1997), who “shows the learner the direction in which to go, teaches him to find his own path, to retrace it, and to continue it” (Ceccato, 1974:137; as quoted by Von Glasersfeld, 1989:12);
- Identifies alternative conceptions and recognizes how students use their own experiences and prior knowledge to construct knowledge and meaning (Gray, 1997);
- Observes, watches, listens and asks questions in order to learn from the students;
- Presents a problem to a certain target group, and deals with usual constraints of time, resources and space (Driver & Oldham, 1986);
- Creates enough opportunities for students and encourages them to make their ideas explicit and communicate them (Driver & Oldham, 1986);
- Is sensitive to and values and respects the ideas and views that students bring with them to the classroom (Driver & Oldham, 1986). The educator



explores the path of the learner and builds a model of the learner's conceptual understanding to adapt applicable instructional activity (Von Glasersfeld, 1989);

- Gives opportunity for feedback and reflexivity (Driver & Oldham, 1989);
- Uses conceptual conflict and critical questions as an instructional strategy to encourage students debate amongst themselves (Roth, 1990:162);
- Encourage student-student and student-teacher dialogue. When students discuss a problem, there should be little or no interference from the educator (Von Glasersfeld, 1989);
- Offers options and choices to the students by means of negotiation. Students may negotiate which curriculum themes to focus on, the selection of literature from a predetermined range, in the design of their assignments within pre-established parameters and the assessment of assignments. Negotiation leads to ownership, ownership leads to motivated learners who work harder and better (Gray, 1997); and
- Considers the individuality of students' learning by identifying cultural differences, different learning styles and individual' initial understanding of their conceptions to enable instruction to have personal relevance to students (Pope & Gilbert, 1983).

Imenda (2005b) states that the teacher needs to be aware of the knowledge the students bring to the classroom as a critical building block for successful teaching and learning to occur. On the same note, Driver and Easley (1978) state that classroom experiences need to be designed to lead to conceptual conflict, but students have to be in a non-threatening environment for such a conflict to produce successful conceptual change.

Siemens (2004:1) posits that "behaviourism, cognitivism, and constructivism are the three broad learning theories most often utilised in the creation of instructional environments." Siemens (2004:1) further opines that "these theories, however, were developed in a time when learning was not impacted

through technology.” Furthermore, Siemens (2004) states that technology has reorganised how we live, how we communicate, and how we learn. Therefore, learning needs and theories that describe learning principles and processes, should be reflective of underlying social environments. Vaill (1996:42) also avers that “learning must be a way of being – an ongoing set of attitudes and actions by individuals and groups that they employ to try to keep abreast of the surprising, novel, messy, obstructive, recurring events...”

Driscoll (2000:11) defines learning as “a persisting change in human performance or performance potential...[which] must come about as a result of the learner’s experience and interaction with the world.” This definition encompasses many of the attributes commonly associated with behaviourism, cognitivism, and constructivism – namely, learning as a lasting changed state (emotional, mental, physiological skills) brought about as a result of experiences and interactions with content or other people (Siemens, 2004).

Driscoll (2000:14-17) further explores some of the complexities of defining learning. The debate centres on:

- Valid sources of knowledge;
- Content of knowledge; and
- The final consideration focuses on three epistemological traditions in relation to learning: Objectivism, pragmatism, and interpretism.
  - Objectivism (similar to behaviourism) states that reality is external and is objective, and knowledge is gained through experiences;
  - Pragmatism (similar to cognitivism) states that reality is interpreted, and knowledge is negotiated through experiences and thinking;
  - Interpretivism (similar to constructivism) states that reality is internal, and knowledge is constructed.

Furthermore, Siemens (2004) avers that “all of these learning theories hold on to the notion that knowledge is an objective (or state) that is attainable (if not

already innate) through either reasoning or experience.” Behaviourism, cognitivism, and constructivism (built on the epistemological traditions) attempt to address how it is that a person learns (Siemens, 2004).

Behaviourism states that learning is largely unknowable, that is, we cannot possibly understand what goes on inside a person (the “black box” theory). Gredler (2001) expresses behaviourism as being comprised of several theories that make three assumptions about learning:

- Observable behaviour is more important than understanding internal activities;
- Behaviour should be focused on simple elements: specific stimuli and responses; and
- Learning is about behaviour change.

Cognitivism often takes a computer information processing model. Learning is viewed as a process of inputs, managed in short term memory, and coded for long-term recall (Siemens, 2004). Cindy Buell details this process as follows: “In cognitive theories, knowledge is viewed as symbolic mental constructs in the learner’s mind, and the learning process is the means by which these symbolic representations are committed to memory”.

According to Driscoll (2000:376) “constructivism suggests that learners create knowledge as they attempt to understand their experiences.” Behaviourism and cognitivism view knowledge as external to the learner and learning process as the act of internalising knowledge. Constructivism assumes that learners are not empty vessels to be filled with knowledge. Instead, learners are actively attempting to create meaning. Learners often select and pursue their own learning. Constructivist principles acknowledge that real-life learning is messy and complex (Siemens, 2004).

It is also noted that behaviourism, cognitivism, and constructivism have limitations. A central tenet of most learning theories is that learning occurs inside a person. Even social constructivist views, which hold that learning is a social enacted process, promotes the principality of the individual (and her/his physical presence – i.e. brain-based) in learning. These theories do not address learning that occurs outside of people (i.e. learning that is stored and manipulated by technology). These theories also fail to describe how learning happens within organisations (Siemens, 2004). Furthermore, Siemens (2004:2) states that “learning theories are concerned with the actual process of learning, not with the value of what is being learned. In a networked world, the very manner of information that we acquire is worth exploring. The need to evaluate the worthiness of learning something is a meta-skill that is applied before learning itself begins (Siemens, 2004). When knowledge is abundant, the rapid evaluation of knowledge is important. In this way, an entirely new approach is needed. Connectivism attempts to address these limitations.

#### 2.4.11 CONNECTIVISM

Siemens (2004) describes connectivism as a new learning theory for the digital age, which recognises the impact of technology. It is realised that technology performs many of the cognitive operations previously performed by learners. In this regard, new information is continually being acquired; decisions are based on rapidly altering foundations. By way of definition, connectivism is the integration of principles explored by chaos, network, and complexity and self-organisation theories (Siemens, 2004). Siemens thus outlines the basic principles of connectivism as follows:

- Learning and knowledge rest in diversity of opinions.
- Learning is a process of connecting specialised nodes or information sources.

- Learning may reside in non-human appliances.
- Capacity to know more is more critical than what is currently known.
- Nurturing and maintaining connections is needed to facilitate continual learning.
- Ability to see connections between fields, ideas, and concepts is a core skill.
- Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.
- Decision-making is in itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision.

Furthermore, Siemens (2004) states that connectivism is driven by the understanding that decisions are based on rapidly altering foundations. New information is continually being acquired. The ability to draw distinctions between important and unimportant information is vital. Connectivism also addresses the challenges that many corporations face in knowledge management activities. Knowledge that resides in a database needs to be connected with the right people in the right context in order to be classified as learning. Behaviourism, cognitivism, and constructivism do not attempt to address the challenges of organisational knowledge and transference. Siemens (2004) posits that the starting point of connectivism is the individual. Personal knowledge is comprised of a network, which feeds into organisations and institutions, which in turn feed back into the network, and then continue to provide learning to individual. This cycle of knowledge development allows learners to remain current in their field through the connections they have formed (Siemens, 2004).

According to Coetze (2008), connectivism strives to amplify learning, knowledge and understanding through networks – realising that complete knowledge cannot exist in the mind of only one person. Learning is a process of connecting information sources. Connectivism recognises the reality that we live in a technological world. Gonzalez (2004, as quoted by Siemens, 2004) describes the current situation of rapidly diminishing life cycle of knowledge as follows: “One of the most persuasive factors is the shrinking half-life of knowledge, which is the time span from when knowledge is gained to when it becomes obsolete”. In this regard, Siemens (1994) mentions the following trends in learning:

- Informal learning through – where personal networks and completion of work-related tasks becomes more significant;
  - Learning is a continual process – lasting a life time;
  - Decision making becomes very significant;
  - Recognising hidden patterns and altering to form connections between sources of information;
  - Sensitive dependence on initial conditions;
  - Cognitive information being stored and manipulated by technology.
- Following these circumstances, this implies that where to find knowledge is more important than to have the knowledge. In this regard, connectivism adds value to constructivism approaches to learning and teaching in that the emphasis becomes more on personalisation of the learning enterprise – and hence the attainment of tools of learning and conceptual analysis to last one’s entire life span.

According to Siemens (2004) connectivism presents a model of learning that acknowledges the tectonic shifts in society where learning is no longer an internal, individualistic activity. Connectivism provides insight into learning skills and tasks needed for learners to flourish in a digital era.

#### 2.4.12 SUMMARY OF THE LEARNING THEORIES

The major characteristics of the learning theories discussed above are summarised in Table 2.2.

**Table 2.2** The summary of the major characteristics of the learning theories

<b>Learning Theorist</b>	<b>Learning Characteristics</b>
Jean Piaget	Learner actively seeks meaning Intellectual development Knowledge construction with interaction with environment Learning is an active process Interaction with the physical world is crucial What the learner brings to the learning environment and developmental differences in reasoning effect science education
David Ausubel	Preconceptions Structure content as framework of specific concepts Meaningful learning
Jerome Bruner	Learning is an active process in which the learner selects and transforms information using cognitive schema Discovery learning Any subject can be taught to any child at any stage of development
Robert Gagne`	Systematic prerequisite building blocks Nine events of instruction
Joseph Novak	Cognitive development depends on framework and integration of concepts
Ernst von Glasersfeld	Learners construct their own sets of meanings or understandings (radical constructivism) Learners interact with the physical world and others as they build up their conceptions Knowledge is not passively received but actively buit up by the learner
John Dewey	Learner is active and participates in the context of educative experiences or projects that have a structure, flow and energy Learning is enhanced by providing active-based instruction, and promoting learning in collaborative groups
Lev Vygotsky	Learners develop knowledge as a social activity in the context of instructional and cultural frameworks

	Language and culture of the social group plays the crucial role in helping students develop ideas and knowledge.
Behaviourism	Observable behaviours are important Views mind as a 'black box' in the sense that response to stimulus can be observed quantitatively
Constructivism	Learner construct knowledge through personal experience – including social and cultural interaction Learning is an individual process carried out in a person's mind and consciousness Guidance is needed
Connectivism	A learning theory for the digital age, which recognises the impact of technology Learning is a process of connecting information sources.

## 2.5 ACTIVITY THEORY

In this section, Activity Theory (AT) is used to develop an understanding of complex roles and relationships that concern this study. In this regard, this section describes AT, reviews studies which have used AT and applies AT to this study. Historically,

Lev Vygotsky introduced the concept of mediation, principally in response to the defects of stimulus-response behaviourism. The idea is that human behaviour is not simply called forth by stimuli, but is mediated by artefacts that are created to prompt or modulate action (Bakhurst, 2009:199).

Lev Vygotsky's activity theory was first construed as the first-generation model of action. The second-generation model is said to have emerged on the basis of the work of Vygotsky's student called Alexei Leontiev who distinguished between 'action' and 'activity' (Bakhurst, 2009). Engestrom then took up Leontiev's position and schematised the AT in full. Thus, Bakhurst (2009:200) opines that

Engestrom refers to what the diagram models as an 'activity system', and he argued that the dynamics of the system – the forces of its development – results from 'contradictions' between elements. The idea is that the

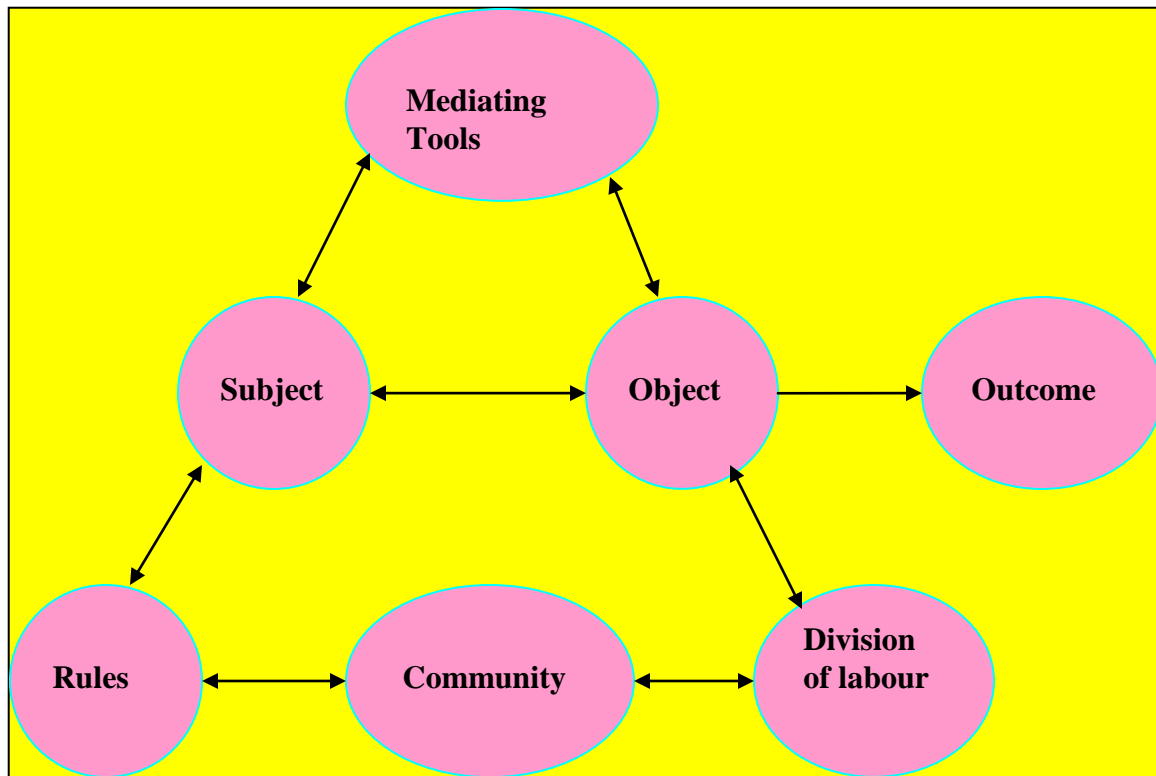


triangle can be applied to concrete subject matter; the terms 'subject', 'object', etc. are to be given specific interpretation depending on the particular case under scrutiny.

Hereunder, the basics components of the AT are described, followed by a review of studies that have used AT.

### 2.5.1 DESCRIPTION OF ACTIVITY THEORY

The researcher believes that the complexity of the relationships involved in education can be analysed using AT. Bakhurst (2009:197) states that AT is increasingly viewed as a potentially fertile paradigm for research in education. In support of Bakhurst, Beauchamp, Jazvac-Martek and McAlpine (2009) see AT as a potentially powerful theory used to develop an understanding of complex roles and relationships in education. Figure 2.1 shows the AT model that is based on Engestrom's (1987) work:



**Figure 2.1** Activity Theory model (based on Engestrom, 1987)

Researchers have found AT useful in studying gender and science education (John-Steiner, 1999), educational psychology (Leadbetter, 2005) and professional learning in higher education (Knight, Tait, & Yorke, 2006). Roth (2004)

argues for the educational usefulness of AT in understanding social processes as individuals produce and reproduce themselves as a member of a community through the distribution, exchange and consumption occurring in the interactions constituting human activity.

Beauchamp, et al, (2009) explain that “AT focuses on the achievement of a long-term goal – an outcome – through mediational means of tools such as language, concepts or signs, within a community governed by rules and division of labour.” Uden (2007:85) avers that AT “focuses on understanding the human activity and

work practices.” By way of description, an activity consists of a subject and an object, mediated by a tool (Kuuti, 1996). Janassen and Rohrer-Murphy (1999:64) also assert that “activities are the human interactions with the objective world and the conscious activities that are part of those interactions.” They further argue that rather than learning before acting, as traditional theories prescribe, AT believes a priori that the human mind emerges and exists as a special component of interactions with the environment, so activity (sensory, mental, and physical) is a precursor to learning.

A subject can be an individual or a group engaged in an activity (Janassen and Rohrer-Murphy, 1999). An activity is undertaken by a subject using tools to achieve an object (objective), thus transforming it into an outcome (Kuuti, 1996). In describing tools, Uden (2007:85) explains that “tools can be physical such as a hammer or psychological such as language, culture or ways of thinking.” Janassen and Rohrer-Murphy, contend that “tools can be anything used in the transformation process (physical, such as hammer or computers or mental, such as models or heuristics).” Kuuti (1996) describes an object as a material thing, less tangible (a plan) or totally intangible (a common idea) as long as it can be shared by the activity participants. Janassen and Rohrer-Murphy (1999) describe an object as the physical or mental product that is sought. They further posit that “the object is acted on by the subject”.

In describing figure 2.1 further, Uden (2007:85) explains that AT “also includes collective activity, the community, rules and division of labour that denote the situated social context within which collective activities are carried out.” Furthermore, Uden (2007:85) describes community, rules and division of labour as follows:

Community is made up of one or more people sharing the same object with the subject. Rules regulate actions and interactions with an activity. Division of labour informs how tasks are divided horizontally between

community members. It also refers to any vertical division of power and status.

In this regard, “the community consists of the interdependent aggregate (e.g., designers within the organisation, subject matter experts, designers within professional associations, customers” (Janassen & Rohrer-Murphy, 1999:64).

Just as tools mediate the relationship between subject and object, rules mediate the relationship between subject and community (Uden, 2007). Similarly, division of labour mediates between community and object (Uden, 2007). AT is “often associated with three levels describing the hierarchical structure of activity” (Uden, 2007:85). Each activity is conducted through actions of an individual, directed towards an object or another object. Activities take place in a certain situation with a specific context (Engestrom, 1987). The distinction between ‘action’ and ‘activity’ is that “an action is conducted by an individual or group to fulfil some ‘goal’, whereas an activity, in contrast, is undertaken by a community (deploying a division of labour, and various means of production) and it has an ‘object’ and a ‘motive’ (Bakhurst, 2009). Bakhurst (2009:200) explains that “both action and activity are contrasted with ‘operations’, which are habituated behaviours provoked by certain conditions.

## 2.5.2 REVIEW OF STUDIES THAT HAVE USED ACTIVITY THEORY

AT as used by Janassen and Rohrer-Murphy (1999); Uden (2007); Beauchamp, *et al* (2009); Margaryan, Collis and Cooke (2004); McDonald and Twining (2002); and Riickriem (2010) are reviewed in this study. In Blacker’s (2007:2) view, AT offers a way of synthesising and developing relevant notions. It also examines the nature of practical activities, their social origins, and the nature of the ‘activity systems’ within which people collaborate (Blacker, 2007).

The study by Beauchamp, *et al* (2009), on doctoral education, describes a pilot study that used AT to shape a methodological tool for better understanding the tensions inherent in the doctoral experience. They posit that doctoral students may function within a range of activity systems (Beauchamp, *et al*, 2009). In their study, they “looked to AT as a way to examine what doctoral students do, with whom they interact, the tensions they experience and how their interactions influence their (students) developing sense of identity” (Beauchamp, *et al*, 2009).

Thus, the outcome of a doctoral student is completing his or her PhD. Here a doctoral student is the subject and the object for the student is completing the paper. With regard to the division of labour, the professor contributes input and feedback, the student researches and writes, other students may participate in helpful discussions. This division of labour is governed by rules and expectations. The supervising Professor, PhD student and other professors and PhD students form part of the community. Their study looked at library resources including human assistance, or a computer as mediating tools. Thus, there is an interaction between the subject and the community in pursuit of an object or purpose.

The study by Uden (2007) also reports the application of AT. Uden (2007) believes that AT, as a social and cultural psychological theory, can be used to design a mobile learning environment. Uden’s study presents the use of AT as a framework for describing the components of an activity system for the design of a context-aware mobile learning application (Uden, 2007). Uden (2007) further states that mobile telephone ownership and usage is almost ubiquitous among student communities. Furthermore, Uden (2007) avers that “the increasingly powerful networks and handsets are making mobile learning a potential reality.” Danesh, Inkpen, Lau, Shu & Booth (2001) opine that Mobile Technology also opens up the potential for children’s group collaboration. In the same vein, Rogoff (1990); Topping (1992); Wood and O’Malley (1996) posit that “group work with students and the research on psychology in education has demonstrated

clear benefits of collaborative learning for young children.” According to Uden (2007:94), AT for mobile technology learning is used in the following manner:

*Subject (User):* The subject-user is the learner (information about learners and action) and physical environment of the learner.

*Mediating Tools:* The main tool here is the mobile device (mobile technology) used by the learner, and any other non-computing tools such as books, manuals, notepads, internet, etc.

*Object:* User intention, objective including raw material that will be transformed to achieve an outcome. In this case, the object is the learning of a particular concept.

*Community:* Social and physical environment of other users that might have influence on the user’s activity.

*Rules:* Can be explicit or implicit such as rules of engagement in the use of mobile devices, university regulations, etc.

*Division of labour:* Roles of user learner according to the relationship between them and community or user’s location. Who can perform which task?

With the use of mobile technology learning, Uden (2007:82) opines that “students can move around and interact with other students in different environments.” One of the benefits of using AT for the design and understanding of the mobile learning environment is that learning is fundamentally situated and socially mediated (Engestrom, 1987; Lave & Wegner, 2000).

This study also reviews the study by Margaryan, Collis and Cooke (2004) whose study was based on activity-based blended learning. Margaryan, *et al* (2004:265)

examines how one organization, the Open University of Shell International Exploration and Production (Shell EP), sought to enhance the effectiveness of e-learning by blending technology with social interaction and collaborative learning, work-place-based activities with superior involvement and input from experienced facilitators.

Margaryan, *et al* (2004:266) further explains that “a commitment was made to a Shell-style of blended learning, with blends not only of time and place of participation but also of different forms of activities of communication.” Blended learning at Shell EP thus came to be defined as: Option for different types of learning activities, different types of learning resources, different times and places for learning activities, and different ways that people work and network together. These options were guided by a capable facilitator, involved regular assessment, and were all regulated via a Web-based learning-support environment (Collis, 2002). The key aspects in this approach (activity-based blended learning) included learning activities with direct workplace relevance; a stress on obtaining line manager support through a tool called the learning agreement, in which participants and the line manager agreed on a change in performance to be seen as a result of the course (Bianco & Collis, 2003). The study by Margaryan *et al*, (2004) also reflected components of the AT as it was an activity-based blended learning approach. These components were reflected as follows:

*Subject:* Shell EP organisation (workplace learners);

*Object:* learning activities (focus on workplace problems);

*Community:* supervisor, line manager, participants (workplace learners) and instructors or tutors or capable facilitators, Web-based environment;

*Outcome:* change in performance to be seen as a result of the course; enhancing the effectiveness of e-learning by blending technology with social interaction and collaborative learning;

*Division of labour:* line manager supports participants and learners share experiences;

*Mediating tools:* learning agreement; technology resources, TeleTOP system; and

*Rules:* participants and manager agreement on a change in performance.

Margaryan, *et al* (2004) further lists five ‘first principles of instruction’ that define good learning settings design as developed by Merrill (2003): (a) learners are engaged in solving real-world problems; (b) existing knowledge is activated as a foundation for new knowledge; (c) new knowledge is demonstrated to the learner; (d) new knowledge is applied by the learner; and (e) new knowledge is integrated into the learner’s world. These principles are said to form the theoretical framework for the redesign of the blended learning courses for the Shell Open University (SOU). Margaryan, *et al* (2004:268) further state that “one of the key enablers of these learning approaches is Web-based technology.” As Winnips (2001:34) opines:

The use of *technology* can shift the balance in interactions between *instructor* and *learners* more towards the *learners*. Many of the social constraints that are present in a classroom may not be present in a computer-supported learning environment, thereby providing more equal opportunities for *learners* to initiate interactions.

Margaryan, *et al* (2004) support Winnips by stating that “this is particularly true in learning environments where learners are non-native speakers of the main language of instruction and might often find it difficult to interact with others in a face-to-face environment.” Furthermore, Margaryan, *et al* (2004:272) argue that “technology is an important tool for learning, particularly in terms of facilitating flexibility and reuse of learner submissions.” However, it is important to also note that technology does not replace the central importance of interpersonal contact: among learners, between the course director and learners, between the learner



and his line manager and between the learner and the workplace colleagues (Margaryan, *et al*, 2004). In this regard, “technology is a tool to make this contact richer, more flexible and reusable” (Margaryan, *et al*, 2004:272).

Macdonald and Twining (2002) describe a qualitative study of student and tutor perspectives on the assessment of an innovative undergraduate course at the United Kingdom (UK) Open University which employed an activity-based approach for a networked course (Macdonald & Twining, 2002). They explained that their approach offered:

a new context for constructivism, which maintains that knowledge construction is an evolving process in which socially situated individuals attempt to make sense of new information by relating to familiar contexts and existing conceptions. Importance is placed on understanding, rather than on memorisation and reproducing facts, on experiences in the learning environment, and on the contribution of social interaction and collaboration to problem solving. The objective is to encourage self-directed learning and metacognitive development (Macdonald & Twining, 2002:603-604).

In this study AT was used or applied in the following manner:

*Subject:* distance students

*Object:* self-directed learning, metacognitive development and assignment writing;

*Community:* electronic community of learners and tutors;

*Outcome:* improved performance in assignments

*Division of labour:* tutors moderate and give feedback while students engage on inline discussions in groups, do assignments and search for resources on the internet. Students were expected to email assignments to their tutors for feedback.

*Mediating tools*: electronic resources, computers and authorising tool called HyperNote for hands-on experience of ICT); and

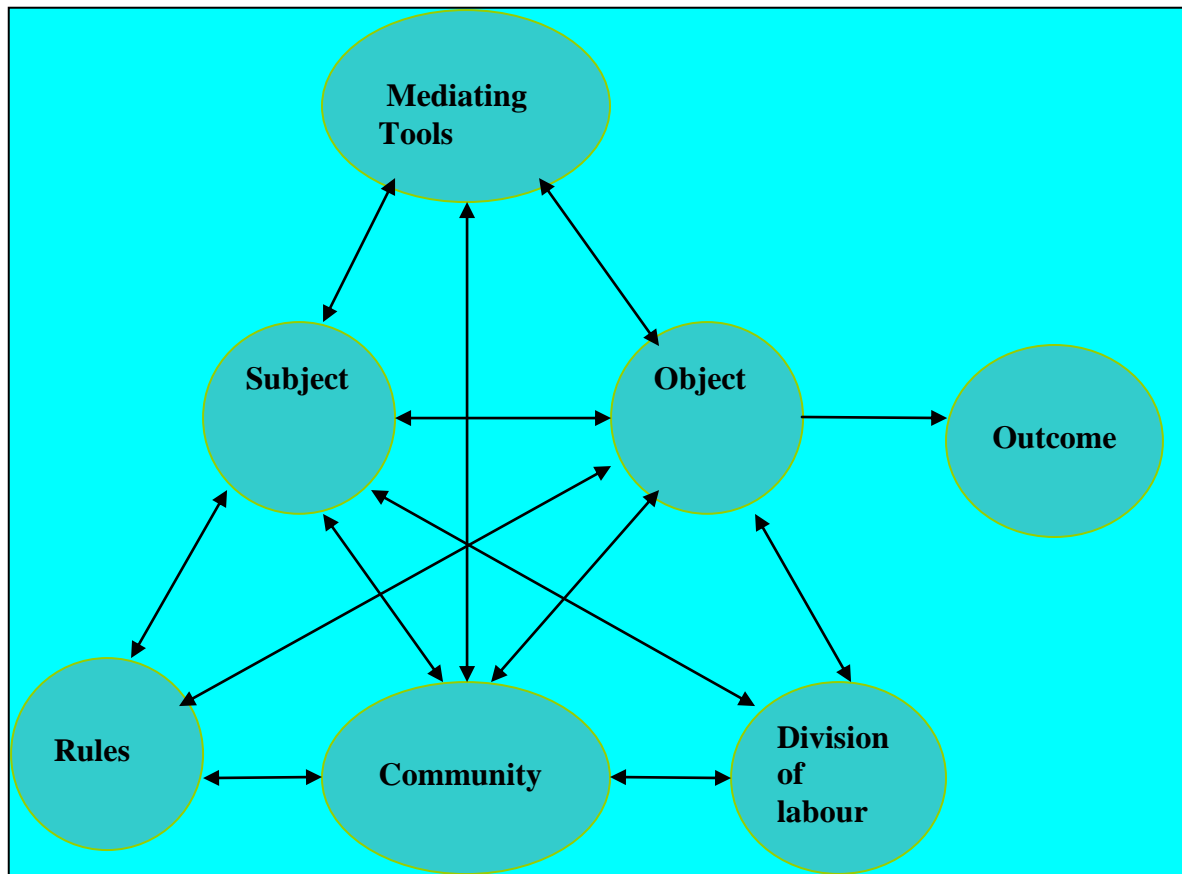
*Rules*: students to meet assignment's technical specifications, students follow instructions and expectations of the course.

This section has presented a review of a number of studies that have used AT. The reviewed literature shows that all the components of AT would be important to a research project such as this one. In the next section, the researcher looks at AT as applied to this study.

### 2.5.3 ACTIVITY THEORY AS APPLIED TO THIS STUDY

Janassen and Rohrer-Murphy (1999:61) aver that AT “provides an appropriate framework for analysing needs, tasks, and outcomes for designing constructivist learning environments (CLEs)”. They further argue that AT “is a socio-cultural, socio-historical lens through which designers can analyse human activity systems” (Janassen & Rohrer-Murphy, 1999:61). Furthermore, they posit that AT “focuses on the interaction of human activity and consciousness within its relevant environment context” (Janassen & Rohrer-Murphy, 1999:61).

This study was also interactive in that the researcher had to interact with learners during the three instructional interventions. The study involved a number of activity systems. Nardi (1996) opines that the production of any activity involves a subject, the object of the activity, the tools that are used in the activity, the actions and operations that affect an outcome. This section therefore presents the use of AT as a framework for describing the components of the activity system for interventions regarding the alleviation of conceptual difficulties and alternative conceptions in mechanics for grade 12 physical science. The components (i.e., mediating tools, subject, object, goal or outcome, division of labour, community and rules) of the AT as applied or used in this study are shown in the Figure 2.2:



**Figure 2.2** Activity System (based on Engeström, 1987) for three intervention groups (traditional, OBE and blended group)

### 2.5.3.1 AT as applied to the traditional intervention group

With regard to the traditional intervention, the teacher remained in complete control of the class. He was also a disseminator of information. All the classroom proceedings were teacher-centred. There was little or no interaction among the learners. The teacher made use of questions sometimes to check learners' attention. The traditional approach was based on Ausubel's reception learning (Ausubel, 1968).

Thus, the traditional intervention, learners were recipients of information and only relied on their memory to remember what was learnt in class. Ausubel (1962) makes a distinction between rote learning and meaningful learning, which is

important for higher order thinking. Rote learning occurs when the learner memorises information in an arbitrary fashion, while on the other hand, meaningful learning is part and parcel to higher order thinking (Ausubel, 1962). The knowledge or information is stored in an isolated compartment and is not integrated into the person's larger cognitive structure. Ausubel (1962:215-216) further asserts that "rotely learned materials are discrete and isolated entities which have not been related to established concepts in the learner's cognitive structure". The AT is applied to this intervention group in the following manner:

The subjects were 35 grade 12 physical science learners. The main object was the traditional curriculum which was designed to address the conceptual difficulties and alternative conceptions in grade 12 physical science mechanics. The expected outcome was the alleviation of conceptual difficulties and alternative conceptions in grade 12 physical science mechanics. The subject and the object were mediated by prescribed textbooks, assignments, worksheets and TBM (used as both pre- and post-test) which were tools for the traditional intervention group. The teacher and the group of thirty five (35) learners formed the community as they were sharing the same object with the subjects. With regard to the division of labour, the teacher prepared worksheets, TBM, provided input and feedback to learners. Learners received information, completed worksheets and wrote the TBM. Learners had to follow the rules as outlined in the TBM, worksheets and also to be silent while the test or lessons were in progress.

#### **2.5.3.2 AT as applied to the OBE intervention group**

Regarding the OBE intervention group, the teacher became a facilitator of learning. All the classroom proceedings were learner-centred. There were interactions among the learners and between the learners and the educator. The teacher made use of questions sometimes to check learners' attention. It was expected that the OBE approach would promote conceptual understanding. This intervention was based on the constructivist way of teaching and learning.

This section describes a process for using AT as a framework for describing the components of an activity system that can be modeled in constructivist learning environments (CLEs). Janassen and Rohrer-Murphy (1999:61) assert that "the epistemic assumptions of constructive learning are different from those of traditional instruction." They further argue that "a powerful framework for analysing needs, tasks, and outcomes for designing CLEs is provided by AT" (Janassen & Rohrer-Murphy, 1999:62). Furthermore, they maintain that "the assumptions of AT are very consonant with those of constructivism, situated learning, distributed cognitions, case-based reasoning, social cognition, and everyday cognition that underlie CLEs" (Janassen & Land, 1999).

The subject here also was a group of 35 grade 12 physical science learners. The main object was the OBE curriculum which was designed to address the conceptual difficulties and alternative conceptions in for grade 12 physical science mechanics. The expected outcome was the alleviation of conceptual difficulties and alternative conceptions in mechanics for grade 12 physical science. The subject and the object were mediated by textbooks that were used as references, peer-controlled group assignments, worksheets and TBM (used as both pre- and post-test), OHP and transparencies, which were tools for the OBE intervention group. The teacher and the group of thirty five (35) learners formed the community as they were sharing the same object with the subject. With regard to the division of labour, the teacher prepared worksheets, TBM, provided input, responsible for facilitation, organised learners into small groups, allowed the learners to interact through discussions, gave feedback to learners. Learners discussed and solved mechanics problems in small groups, completed worksheets, responsible for peer assessment, and wrote TBM. Learners had to follow the rules as outlined in the TBM, worksheets and assignment. There were also rules that governed group discussion (for example, meaningful discussions with appropriate noise level and avoidance of irrelevant matters).

### **2.5.3.3 AT as applied to the blended intervention group**

With regard to the blended intervention, the teacher became a facilitator of learning as for the OBE intervention. He allowed learners to interact with each other and with the facilitator. All classroom proceedings were learner-centred. There were a lot of learner-learner and educator-learner interactions through discussion, as well as question and answer methods. In this approach, the facilitator employed a variety of teaching strategies including the lecture/telling method and computer-mediated teaching to cater for and accommodate different learner characteristics in the group. It was also envisaged here that the blended approach would also promote conceptual understanding.

This approach (blended) was based on the constructivist and connectivist theories of learning, as earlier discussed in this chapter. Thus, the blended approach, as a method that mixes various teaching and learning strategies, also involved technology as an important tool for learning. Margaryan, *et al* (2004) opine that technology is an important tool for learning, however, it does not replace the central importance of interpersonal contact: among learners, between the educator and the learners, between the learner and online manager. Thus, Margaryan, *et al* (2004:272) advise that technology should therefore be used as a tool “to make this contact richer, more flexible and reusable.” Macdonald and Twining (2002:604) posit that “activity-based approach has constructivist aims, and exploits both collaborative interaction and access to information-rich resources.”

The subjects here were also 35 grade 12 physical science learners. The main object was the blended curriculum which was designed to address the conceptual difficulties and alternative conceptions in grade 12 physical science mechanics. The expected outcome was the alleviation of conceptual difficulties and alternative conceptions in grade 12 physical science mechanics. The subject and the object were mediated by textbooks that were used as references, peer-controlled group assignments, worksheets and TBM (used as both pre- and

post-test), OHP and transparencies, electronic resources, laptop computer, data projector, which were tools for the blended intervention group. The teacher and the group of thirty five (35) learners formed the community as they were shared the same object.

With regard to the division of labour, the teacher prepared worksheets, TBM, provided input, responsible for facilitation, organised learners into small groups, allowed the learners to interact through discussions, gave feedback to learners. With regard to Web-based learning the facilitator also played a learner role. The facilitator was also responsible for the operation of electronic resources (laptop, data projector, and so on). Learners discussed and solved mechanics problems in small groups, completed worksheets and wrote TBM (as both pre- and post-test). Learners had to follow the rules as outlined in the TBM, worksheets and assignment. There were also rules that governed group discussions (for example, meaningful discussions with appropriate noise level and no room for irrelevant matters).

## **2.6 CURRICULUM DEVELOPMENT AND IMPLEMENTATION**

The third research objective concerns the development and implementation of curricular interventions, based on the traditional, OBE and blended approaches. The purpose of curricular intervention development and implementation was to alleviate the conceptual difficulties and alternative conceptions in grade 12 mechanics. A study by Wessel (1999) focused on how students in grade 12 physics actively constructed their knowledge, by using a curriculum which had at its foundation a view that learning was an individual process and that concepts in science were constructed by learners through hands-on activities and personal experiences. Wessel (1999) further emphasized that learning in science was a very complex process partly because of the abstract nature of many scientific concepts and their representation by

mathematics. Wessel, therefore, argues that advances in student performance will require a different approach than the traditional instructional methods.

The term 'curriculum' is derived from the Latin word *currere* meaning 'the course to be run', or 'a task to be completed' (Eisner, 1979:34). This means schools have programmes designed for learners which are to be completed within a specified period of time (Jacobs, Gawe & Vakalisa, 2002). There are, however, different definitions and meanings of the concept curriculum. Eisner (1979:39) defines curriculum as a "series of planned events that are intended to have educational consequences for one or more students". According to this definition, curriculum events are planned to achieve desired results and help learners to learn. In the same vein Popham and Baker (1970:48) conceive of curriculum as "all the planned learning outcomes for which the school is responsible". The curriculum here is seen in terms of outcomes or objectives to be achieved. This study adopt and accepts Rowntree's description of a curriculum: "'curriculum' may include anything from a four-year programme of studies down to a forty-minutes lesson or even briefer episode of planned teaching" (Rowntree, 1982:20).

Educators do not necessarily implement the curriculum at a broader or highest level, but they do so at the classroom level. The classroom is the place for curriculum implementation. Therefore, planning on the part of educators, in terms of lesson plan or curriculum development is essential. Carl (2009:208) argues that the classroom is that level or field in which the teacher may become most actively involved in curriculum development and also the level at which actual implementation takes place. The teacher is the developer, initiator, manager, analyser and evaluator of the curriculum.

A change towards a constructivist approach – i.e. from a traditional to a transactional curriculum, has implications for curriculum development to involve an environment in which children can construct their own understanding (Gray, 1997).



Spady (2008:3) recommends the following aspects in designing an outcome-based curriculum:

- to design systematically back from the ultimate, desired end, which are referred to as the outcomes of significance;
- to put in place the enabling skills to provide a clear pathway to that end; and
- to keep the outcomes always in sight.

Considering the constructivist nature of many curricula, especially the OBE curriculum in SA, Gray's (1997) asserts that curriculum development doesn't occur through forcing of new ideas, but through personal development, which includes teacher change and growth. This is the responsibility of the teachers, although they should be provided with opportunities, resources, support, encouragement and recognition.

Gray (1997:4) describes the change of instruction from a "transmission curriculum", where a teacher transmits information to students who passively listen and acquire facts, to a "transactional curriculum", where students are actively involved in their learning. In the history of curriculum development, Imenda (2002) identifies three perspectives: inputs perspective, process perspective and outcomes perspective.

According to Driver and Oldham (1986) the *inputs* needed for a curriculum design are content, which includes the experiences students should be exposed to; alternative conceptions of students; perspectives on the learning process and the selection of activities; teachers' practical experience of students, institutions and classrooms. Imenda (2002) adds on these: qualifications of the educators; available facilities; all physical, financial and material requirements.

The *process perspective* refers to the emphasis on the implementation which includes the instructional methods and the quality of the learning experiences the learner goes through (Imenda, 2002).

On the other hand, the *outcomes perspective* entails a focus on the final skills and competences the learner is expected to possess after a defined learning cycle (Imenda, 2002a).

Imenda (2002) is concerned about the danger of an imbalance among these three perspectives, given that they are all equally important for any curriculum change to succeed. Several studies, e.g. Driver (1983) and Driver and Oldham (1986) emphasize that content, an inputs perspective, and instructional methods, a process perspective, should be complementary considerations in curriculum design. Curricula should incorporate conceptual development as part of the documentation, rather than remaining external to curricula as an instructional strategy.

Imenda (2002) characterises the education system and the nature of any curriculum in terms of:

- (i) foundations, which include the curriculum's pedagogical, philosophical, psychological and sociological foundations,
- (ii) contextual elements, which include legislation and policies, structure and organization and curricular descriptions, and
- (iii) Actualisation, which includes contextual elements in practice and responsibilities of government, the institution and the individual practitioner.

Imenda (2005) recommends that in developing the necessary education concepts and principles, a constructivist approach to teaching and learning be adopted. Constructivists posit that modern curricula must have at their foundation a view that student learning is an individual process and personal

experiences and hands-on activities promote a better construction of concepts by learners (Wessel, 1999).

A study done by Strauss (2000) focused on the effect different theories about cognitive development have on curriculum development, teaching and learning – and saw a curriculum as the external expression of an underlying conceptual system held by the curriculum developer about the nature of the subject being taught. Thus, Strauss (2000) concluded that learners used different routes to learn. Educators don't know which route is more suitable for any one learner, but each learner learns to know what works for him or her during teaching, and what is not. Consequently, Strauss (2000) contends that learners and educators are partners who should guide and assist each other.

Wessel (1999) recommends and suggests the following in implementing in physics and science curricula:

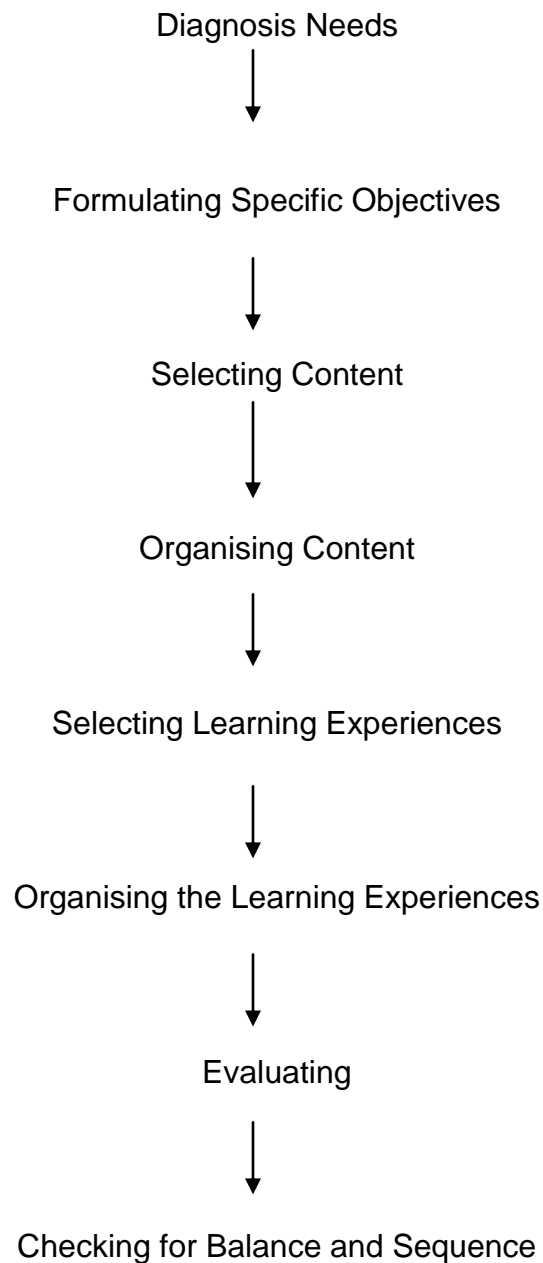
- Instruction has to be modified to assist students in achieving meaningful learning of abstract concepts, instead of simply memorising formulae and definitions.
- Secondary physics curriculum guides should include guidance to teachers in promoting student conceptual development and not only student learning in terms of outcomes of learning objectives.
- Reduce the amount of content in physics curricula: by making content more relevant and meaningful for students, will be a constructive change in assisting students to achieve meaningful learning within secondary school physics.

### **2.6.1 Curriculum Design Models and Planning of Lessons**

Research reveals that curriculum design models have evolved from classical “linear models”, through the “interactive models” to the “cyclical models” (Tyler, 1949; Brady, 1995; Bell & Lefoe, 1998; Prideaux, 2003). Imenda (unpublished) states that “the Tyler Rationale, as it is commonly referred to, warrants that the curriculum designing process starts with the ‘educational purposes’”. On his part, Prideaux (2003:268) observes as follows:

The statements of purposes have become known as “objectives – thereby earning this model the name: objective model. The specification of objectives is then followed by (a) the “selection of learning experiences”; (b) appropriately organizing and effecting the selected learning experiences; and (c) the “evaluation” of both the student attainment of the effectiveness of the learning program as a whole.

Taba (1962: 347-379) refined this model (objectives) by adding four more steps resulting in the following:



**Figure 2.3** Taba's Linear "Objectives" Model

However, Taba's curriculum model has been a subject of criticism for (a) being linear, and (b) being based on "behavioral" objectives (Imenda, unpublished). In this way, critics have argued that a great deal of worthwhile learning is not

amenable to observation or measurement, and that teaching which only addresses aspects of learning which can be measured confines and trivialises knowledge (Bell & Lefoe, 1998:68). In this regard, it is further argued that the model,

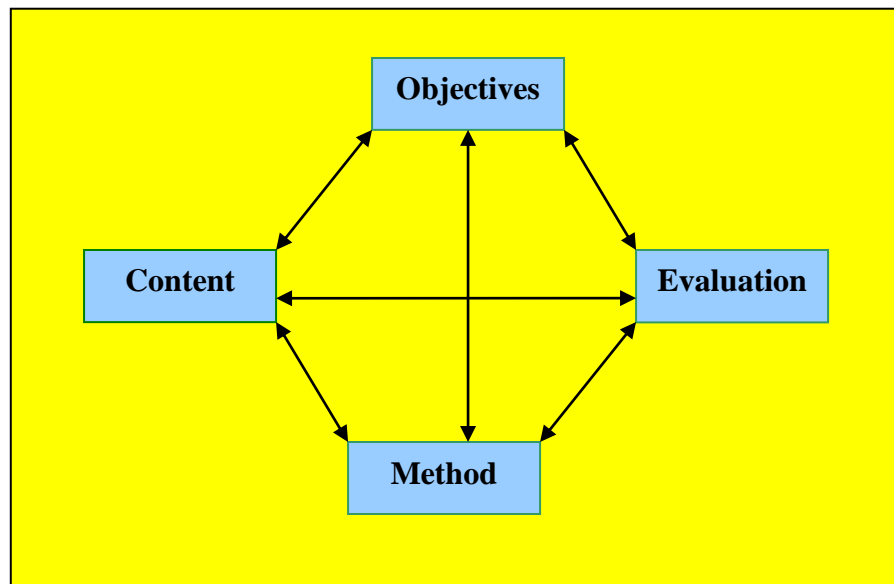
Restricts the curriculum to a narrow range of student skills and knowledge that can be readily expressed in behavioral terms [... and accordingly] higher order thinking, problem solving, and processes for acquiring values may be excluded because they cannot be simply stated in behavioral terms (Prideaux, 2003:269).

Imenda (unpublished) further posits that to date, it appears that there is no other option available to teachers and other educators, other than formulating “objectives”. Furthermore, Imenda (unpublished) avers that a properly formulated behavioral objective consists of three “terms”, i.e. a condition statement (stating the context); a performance (outcome statement); and the evaluation term (stating the minimum assessment criteria with regard to the expected performance).

Regarding the narrowness of behavioural objectives, Prideaux (2003:269) recommends that:

Care should be taken, however, to focus only on “significant and enduring” outcomes. An exclusive concern with specific competencies or precisely defined knowledge and skills to be acquired may result in the exclusion of higher order content that is important.

On the question of linearity of the “objectives” models, the criticism has been that an “interactive” model would be more practical in that it would allow information obtained during any stage to be used anywhere else in the design process (Imenda, unpublished). The linearity criticism has led to the evolution of interactive models. Figure 2.4 below shows an example of an interactive model.

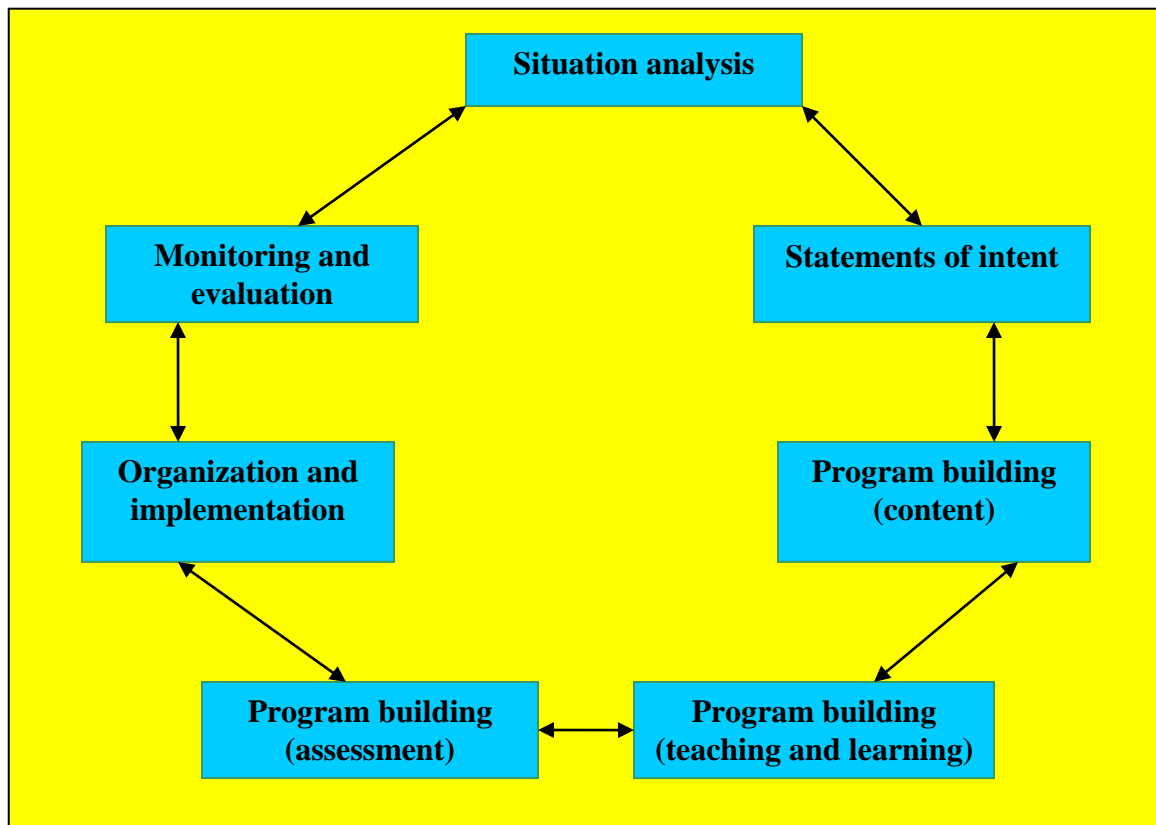


**Figure 2.4** An example of an interactive model [Source: Bell & Lefoe, 1998:67]

The rationale behind the Interaction Model is at realities of design practice occasion that:

The design of the element will influence and possibly change the design decisions for other elements. For example, method might be specified first but altered later as a result of assessment decisions. This model makes it possible to specify learning objectives after all other elements have been decided (Bell & Lefoe, 1998:67).

Bell and Lefoe (1998:67) make this observation in their statement that “the interaction model specifies the same design elements as the linear, objectives model; however, the design process can begin with any of the other elements”. Imenda (unpublished) argues that the notion of interactive curriculum design models has led to “cyclical models” which, again, do not necessarily have any new elements – other than to emphasise the interactivity of the elements. Figure 2.5 shows an example of a cyclical interactive model.



**Figure 2.5** An example of a cyclical model [Source: Prideaux, 2003:270]

According to Prideaux (2003), the cyclical models emphasize the importance of “context” in the curriculum design process – in addition to interactivity. In this regard, Dillon (2003:218) observes as follows:

Some argue that context is all important – that learning is situated in specific context (hence, situated cognition) – i.e. it is difficult to transfer knowledge learned in one context to another.

Hence, it is further argued that it is important to emphasize, not only the cognitive elements of learning as demanded by the logic of the subject matter, but also the social context within which learning takes place (Imenda, unpublished). With regard to constructivism, Dillon (2003:218) makes this point in the following words:



Other, more useful, views of learning claim that we build (construct) knowledge through social interactions – so that through dialogue, we become more knowledgeable. Such constructivist theories of learning have been around for some time – Piaget was, in effect, a constructivist.

In this regard, Carl (2009:209) maintains that a thorough knowledge of the relevant curriculum models can assist with meaningful planning. The curriculum models may be adapted to particular needs and the goal of the syllabus and allow a great degree of flexibility should adjustment have to be made. The planning function is a basic function of lesson preparation, and in turn, involves other responsibilities.

### **2.6.2 Implementation of Instructional Planning**

After planning, the next curriculum function would be to apply or implement the lessons which have been planned. Some of these curriculum actions would have a direct connection with instruction, while other actions would have a more indirect link, as indicated by Carl (2009:209) as follows:

- Direct instructional activities
  - Direct transfer of learning content;
  - Utilisation of educational methods and media;
  - Evaluation/assessment of effectiveness of the instructional-learning situation;
  - Evaluation/assessment of suitability of lesson content; and
  - Distribution of homework.
- Instructional-linked activities
  - General organisation of classroom;

- Checking and correcting homework;
- Diagnoses of learning errors and taking of remedial action;
- Revision of additional instruction (for example, outside normal school hours);
- Evaluation activities, such as the drawing up and revision of test and examination question papers, and correcting the answers; and
- Conducting personal self-evaluation.

Successful classroom instruction cannot be achieved through one approach. As Carl (2009:210) opines “it is during these implementation actions that the teacher may make a direct contribution in order to extend and strengthen his/her particular subject”. Carl (2009) further opines that in implementation, the educator can experiment with renewing educational methods, apply a variety of media and implement or test other renewal ideas.

With regard to experimentation, Taba (1962: 464-465) gives strong support to this concept of experimentation by stating as follows:

Perhaps the greatest need is for protecting experimentation. Teachers need to try out new and unfamiliar ideas. But above all, they need to feel free to experiment. They need assurance that the mistakes which occur in the course of experimentation will not be held against them.

Thus, the school climate needs to be favourable for teachers to experiment with their subjects. To enable experimentation to succeed, instructional leaders and the school principal should give a great deal of support to teachers. Teachers need to be encouraged to think experimentally. Accordingly, Carl (2009:210) further posits that “experimental thought is reflected by teacher actions within the classroom and appears to be an important component of curriculum development and change”. To achieve this mindset, teachers need to be creative and not lament about lack of resources at schools.

### 2.6.3 General Curriculum Functions

Carl (2009:211) maintains that “being able to make a real contribution to subject curriculum development requires a thorough knowledge of various aspects and the exercise of certain competencies”. Cawood (1983:2) illustrates some aspects of curriculum development as follows:

- Knowledge and understanding of attitudes towards education;
- Philosophy of life; and
- Educational teaching attitudes.
- Thorough knowledge of the child and a positive adaptation towards children.
  - Positive adaptation to education and educational relations;
  - General curriculum studies;
  - Knowledge, understanding and critical adaptation in regard to overall school-phase curricula; and
  - Knowledge, understanding and critical adaptation in regard to the particular school’s curriculum.
- Particular learning area or subject curriculum studies.
  - Own subject/learning area specialisation and subject/learning area knowledge;
  - Knowledge, understanding and competence in regard to particular subject didactics/learning area studies; and
  - Knowledge, understanding, competence and critical adaptation in regard to a particular subject curriculum/learning area.

- Didactic knowledge and competence.
  - Knowledge of, and competence in, curriculum development at meso- and micro-levels;
  - Knowledge of, and competence in, goal formulation and goal-orientated teaching;
  - Knowledge of, and competence in, formulation and teaching using an outcomes-based approach;
  - Knowledge of, and competence in, content selection and classification;
  - Knowledge of, and competence in, educational methods and media; and
  - Knowledge of, and competence in, evaluation of the child and curricula.
- Knowledge of, and utilisation of, mechanisms/channels to enhance curriculum development.
  - Knowledge and utilisation of curriculum development channels/mechanisms; and
  - Support of instructional leaders.

The above aspects of curriculum development are essential in the development of the curriculum that supports learning. The educator is not only the instructor but also the facilitator of learning.

#### **2.6.4 Designing the NCS Learning Programme**

A learning programme assists teachers to plan for sequenced learning, teaching and assessment in grades 10 to 12 so that all LOs in a subject are achieved in a progressive manner (Department of Education, 2005). The Department of

Education (2005:3) therefore recommends the following three phases of planning:

- Phase 1 – develop a *Subject Framework* for Grades 10 to 12;
- Phase 2 – develop a *Work Schedule* for each grade; and
- Phase 3 – develop *Lesson Plans*.

The Department of Education (2005:3) further recommends that the teachers of a subject at a school or cluster of schools first put together a broad subject outline (Subject Framework) for the three grades to arrive at an understanding of the content of the subject and the progression which needs to take place across the grades. This will assist with the demarcation of content for each grade. Thereafter, teachers of the subject teaching the same grade need to work together to develop a year long Work Schedule. The work schedule should indicate the sequence in which the content and context will be presented for the subject in that particular grade. Finally, individual teachers should design lesson plans using the grade-specific work schedule as the starting point. The lesson plans should include learning, teaching and assessment activities that reflect the LOs and ASs set out in the Subject Statement. Learning Programmes should accommodate diversity in schools and classrooms but reflect the core content of the national curriculum (Department of Education, 2005:4).

Carl (2009:209) asserts that within the classroom, the teacher will play a special role particularly in regard to the planning of lessons and lesson units. Carl (2009:209) further state that the teacher must be able to identify and formulate objectives, analyse content, plan learning experience opportunities, consider teaching methods and the sequence of constructional learning events and be able to evaluate them effectively. In an OBE context, teachers should plan lessons based on the learning outcomes and assessment standards of the

subject, the focus thus being on achieving the critical outcomes and learning outcomes.

According to the Department of Education (2005:5), lesson plans are not equivalent to periods in the school timetable. Each lesson plan should contain a coherent series of teaching, learning and assessment activities. A lesson plan adds to the level of detail for each issue addressed in the Work Schedule. A Work Schedule is a carefully prepared document that reflects what teaching and assessment will take place in the 36 – 40 weeks of the school year (Department of Education, 2005:5). A lesson plan also indicates other relevant issues to be considered when teaching and assessing a subject.

## **2.7 THE TRADITIONAL, OBE AND BLENDED APPROACHES TO TEACHING AND LEARNING**

In this section, the literature pertaining to the traditional, OBE and the blended approaches to teaching and learning is reviewed. The relationship between the NCS and each instructional approach (traditional, OBE and blended), outcomes in terms of AT, assessment (or continuous assessment) in each approach was reviewed and discussed.

Learning is not a static activity but an active process. Thus, learners need to be given opportunities to engage with the subject content. This means that the transmission mode of teaching, such as lecturing without expecting learners to respond or engage in activities during the lecture, is not appropriate if used as the sole approach to teaching. Educators need to use a variety of teaching strategies so as to keep learners actively involved in the learning. Hence, the three approaches are hereunder reviewed and discussed, that is, the traditional, OBE and the blended teaching and learning approaches.

### 2.7.1 THE TRADITIONAL APPROACH TO TEACHING AND LEARNING

The traditional approach to teaching and learning is characterised by the teacher standing at the front of the classroom and the learners sitting at their desks. The teacher is the dominant instructional instrument and the intervention is mostly teacher centred and learners are most of the time inactive. Coetzee (2008:94) posits that traditional instruction methods lack interaction and communication amongst students themselves. The passiveness of learners is attributed to a number of factors, such as, the students' background, the lack of confidence, the lack of competence in the English language which is the instructional medium (Olivier, 1988; Tshungu, 1982; Mawasha, 1986; Imenda & Muyangwa, 2006; and Coetzee, 2008). Sometimes learners experience constraints with regard to the typical science classroom – such as inadequacy of instructional materials, time and facilities.

In the traditional approach to teaching and learning, text and memorisation of facts is emphasised, the educator is responsible for learning and is also the expert who knows the answers to the questions he/she has constructed. However, Imenda (2010:3) argues that although the usefulness of other teaching strategies is being widely examined today, the lecture mode of teaching and learning (traditional approach) still remains an important way to communicate information. By way of definition, lecture is an instructional approach where the lecturer, or and educator, talks while learners are quiet: perhaps listening (Imenda, 2010:2). Alonso, Lopez, Manrique and Vines, 2005:217) assert that the conventional education system has focused on transmitting the teacher's knowledge (what the teacher knows, which is not necessarily what he or she should know) to students. In so doing, conventional education has paid less attention to the other aspects of education, namely, learning. Wenger (1998) posits that a form of learning that takes into account individual needs, interests and styles, and that encourages social learning, is preferred. Imenda (2010:4) further gives the advantages of the lecture approach as follows:

- Provides a way to communicate a large amount of information to many listeners;
- Maximises instructor control; and
- Is non-threatening to students when implemented appropriately.

Nonetheless, there are some disadvantages of the lecture approach:

- Minimises feedback from students;
- Assumes an unrealistic level of student understanding and comprehension; and
- Often disengages students from the learning process causing information to be quickly forgotten (Imenda, 2010:4).

Therefore, it is obvious that the lecture approach cannot be used alone for a successful lesson. It can be blended with other teaching strategies since it remains an important way to communicate information.

In the same vein, Imenda (2010:4) also gives some tips on using the lecture approach successfully:

- Fit the lecture to the audience;
- Focus your topic - remember you cannot cover everything in one lecture;
- Prepare an outline that includes 5 – 9 major points you want to cover in one lecture;
- Organize your points for clarity;
- Select appropriate examples;
- Gain attention of students;
- Present more than one side of an issue and be sensitive to other perspectives;
- Repeat points when necessary;
- Be aware of your audience – notice their feedback;
- Be enthusiastic – you don't have to be an entertainer but you should be excited by your topic'
- Elicit student participation;



- Provide feedback and positive re-enforcement;
- Obtain feedback; and
- Enhance retention and transfer;

The above-mentioned tips, notwithstanding, it is still argued that the lecture method cannot be successfully used alone. Student participation can only be meaningfully elicited through discussion, communication, as well as question and answer methods. Mintzes, Wandersee and Novak (2001; as cited by Coetzee, 2008:91) state that no single instructional method by itself can adequately reflect the entire multidimensional nature of understanding. Coetzee (2008:91) avers that the choice of instructional strategies depends on a number of factors, including teacher preferences, the concept being developed, classroom facilities, available sources and the group of students being taught.

#### **2.7.1.1 The relationship between the Traditional Approach and NCS**

There is little relationship between the traditional approach to teaching/learning and NCS. The relationship is best looked at in terms of basic principles that govern the traditional approach and the NCS, respectively. The NCS grade 10 – 12 is based on the following principles of which OBE is one of them:

- Social transformation;
- Outcomes-based education;
- High knowledge and skills;
- Integration and applied competence;
- Progression;
- Articulation and portability;
- Human rights, inclusivity, environmental and social justice;
- Valuing indigenous knowledge systems; and
- Credibility and efficiency (department of Education, 2003:1).

The kind of the learner that is envisaged in the NCS is the learner “who will be imbued with the values and act in the interest of a society based on respect for

democracy, equality, human dignity and social justice (Department of Education, 2003:5). In the traditional approach little or no social values are promoted in class. One of the common aspects between traditional and NCS is that both have tests and examinations (summative assessments). Assessment in the NCS is the integral part of teaching and learning (Department of Education, 2005:1; 2007:1).

According to the Department of Education (2003:5), learners emerging from the FET band must:

- Have access to, and succeed in, lifelong education and training of good quality;
- Demonstrate an ability to think logically and analytically, as well as holistically and laterally; and
- Be able to transfer skills from familiar to unfamiliar situations.

It is doubtful that these can be achieved through traditional approach.

#### **2.7.1.2 Instructional Approaches in Traditional Approach**

With regard to traditional approach, the traditional teacher usually stands at the front of the classroom and the students sit at their desks. The teacher (that is, lecturing/telling method) and prescribed textbooks are the dominant instructional method and the intervention (teaching and learning) is teacher centred. The students are most of the time inactive and passive recipients of information. Coetzee (2008) argues that some students expect that instruction should be provided in a direct manner, either through notes or by directly answering their questions. Initially they are not comfortable being actively involved in their own learning. Rather than viewing theory as underlying principle, they appear to view scientific theories as algorithms which could be used to answer problems (Wessel, 1999). Traditional instruction methods lack interaction and communication amongst students and lecturers as well as amongst students

themselves. Students do not usually ask questions, or want to be involved in discussions in class (Giqwa, 1994). Olivier (1988) attributes this passiveness to a number of factors:

- the students' backgrounds, especially the "Black Tradition" (Tshungu, 1982, as cited by Imenda & Muyangwa, 2006);
- the lack of confidence (Jardine, 1986, as cited by Imenda & Muyangwa, 2006);
- the lack of competence in the English language which is the instruction medium (Mawasha, 1986, as cited by Imenda & Muyangwa, 2006).

Coetzee (2008:125) opines that "in traditional science classes, educators usually use questions to involve students". Basically, the educator is constructing a scientific explanation where learners fill in the blank spaces by giving the intended correct responses. Wrong answers are disruptive, because they threaten the story line (Roth, 1990).

The traditional scientific method corroborates new scientific knowledge. The teacher remains in complete control of the class and helps students to avoid making too many unnecessary detours during laboratory work (Abrams, 1998).

Coetzee (2008) posits that despite science education reforms, teachers may still teach the same material using the traditional methods they themselves experienced in college science courses. Abrams (1998) mentions several factors why teachers maintain the status quo:

- they are uninformed about new national standards;
- they do not read the latest educational journals;
- they do not attend any conferences;
- they experience constraints of the typical science classroom – such as inadequacy of instructional materials, time and facilities.

Spady (2008) opines that because of the time constraint, particularly, educators tend to cram their ever expanding curricula into fixed time boxes, no matter how long it might actually take learners to grasp and master it.

#### **2.7.1.3 Outcomes in Traditional Approach in Terms of AT**

Cass, Wedekind and Parker (1997) assert that traditional approach was content-driven and teacher-centred. The term “outcomes” was not in use in the traditional approach, but instead the term “objectives’ was used. Connecting traditional approaches with AT, Nardi (1996) asserts that “the production of any activity involves a subject, the object of activity, the tools that are used in the activity, and the actions and operations that affect an outcome”.

(Janassen & Rohrer-Murphy, 1999:62) describe the subject of any activity as “the individual or group of actors engaged in the activity”. In the case of the traditional approach, the subject is the learner or learners in the whole classroom. The object of the activity is the physical or mental product that is sought. In this way, the object is acted upon by the subject (Janassen & Rohrer-Murphy, 1999:62). In this regard, the object with reference to the traditional approaches is the achievement of the teacher’s objectives. According to Uden (2007), tools can be physical or psychological. In this manner, the tools in the traditional approach are the prescribed textbooks, exercise books, chalk and chalk board. The teacher and the class of students form the community. With regard to the division of labour, teacher disseminates information to students, write notes on the chalk board with learners copying notes to their notes exercise books. As a rule, learners have to keep quiet throughout the learning programme. Students also write tests and examinations and the teacher marks and gives feedback to students.

#### **2.7.1.4 Assessment in Traditional Approach**

Traditionally, assessments were basically tests and examinations that were used as main techniques for assessing students. These were done once at the end of the term or year. It has been suggested that “teachers were more interested in testing students than teaching them” (Cass, Wedekind and Parker, 1997:13). This kind of assessment is commonly known as summative assessment.

*Summative assessment* refers to assessment that takes place at the end of the learning experience for a purpose outside the learning experience. One main test or examination that is written at the end of the school year usually constitutes it. The aim of the assessment is to determine how much of the subject’s content the learners know. Sometimes a teacher is assessing a learner against some kind of norm or average performance of a particular section of the population or age group. Summative assessment provides information to other people, for example, parents and employers (Flanagan, 1998:74; Le Grange & Reddy, 1998:4). When assessment is used to record a judgement of the competence or performance of the learners, it serves a summative purpose. Summative gives a picture of a learner’s competence or progress at any specific moment. It can occur at the end of a single learning activity, a unit, cycle, term, semester or year of learning. Summative assessment should be planned and a variety of assessment instruments and strategies should be used to enable learners to demonstrate competence (Department of Education, 2003:56).

Summative assessment is almost always *norm-referenced*. This means that the learners’ achievement is compared with that of other learners or with pass marks to determine how well the learner is doing. Norm-referenced assessment reflects little about what the learner has mastered or understood. For example, at the teacher-parent meeting held after the mid-year examination, James’ parents are told that he attained 85 marks out of a possible 100 mark for a certain subject area. The teacher further explains that his performance is 15 marks better than the class average and 45 marks above the required pass mark. This leaves

James' parents with a sense that he has "done well", compared with the other learners and the pass mark that were set, but they have very little understanding of James' competence in the subject area. (Flanagan, 1998:74; Le Grange & Reddy, 1998:4).

Cass, Wedekind and Parker (1997) report that with regard to traditional assessment,

Millions of rands were spent annually on organising school-leaving exams. And every year these were disrupted by people stealing and selling exams to learners desperate for a certificate that they believed was a passport to future job success. In schools, more and more time was spent on "control" tests and "trials" and other forms of assessment. All the time spent on testing was taken away from time that teachers could have used for teaching.

This was one the disadvantages of traditional education. No meaning was attached to learning and understanding of concepts.

Dougherty (1997:33) differentiates between formative and summative assessment as follows:

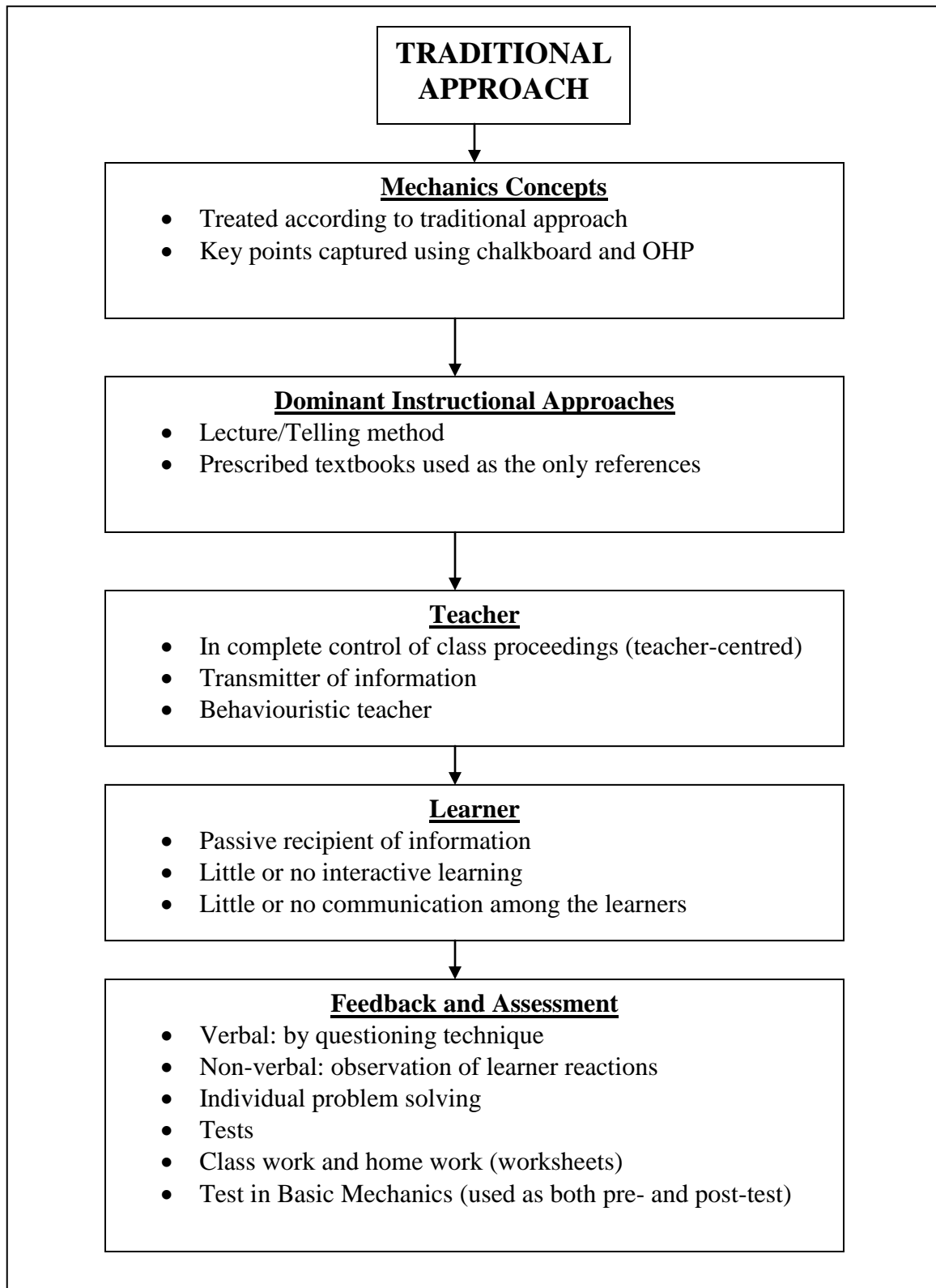
The key difference between assessing summatively and assessing formatively resides in the application of the data the teacher collects. If the teacher uses those data to modify instructional practices in a way that accommodates students' developmental positions and promote more learning, he or she is using assessment in a formative way. Teaching is about what students *learn*, not what the teacher *presents*.

Dougherty (1997:33) further maintains that "if teachers make the commitment to help students learn science conceptually, teachers necessarily must change how they evaluate learning". Traditional assessment is also commonly *norm-refernced* type of assessment.

*Norm-referenced assessment* indicates performance in terms of the relative position held in a specific group (e.g. to perform better than 90% per cent of the class members). Norm-referenced interpretations may relate to local, provincial or national groups, depending on the use to be made of the results. Norm-reference grading is based on comparing learners to one another. The function of each learner's grade is to indicate how the learner performed in comparison with other learners in a specific grouping (Maree & Fraser, 2004:51).

#### **2.7.1.5 Continuous Assessment in Traditional Education**

Assessment in the traditional approach is never continuous. The traditional approach is characterised by tests and examinations towards the end of the term or year. Assessment is only summative. Le Grange and Reddy (2000:5) assert that “traditional teaching practices focus largely on developing a learner's memory capacity. Traditional assessment practices are therefore mostly summative and norm referenced.” Most of the time with the traditional approach is taken by tests and examinations. There is no continuous assessment. Figure 2.6 shows the traditional teaching model as followed in this study.

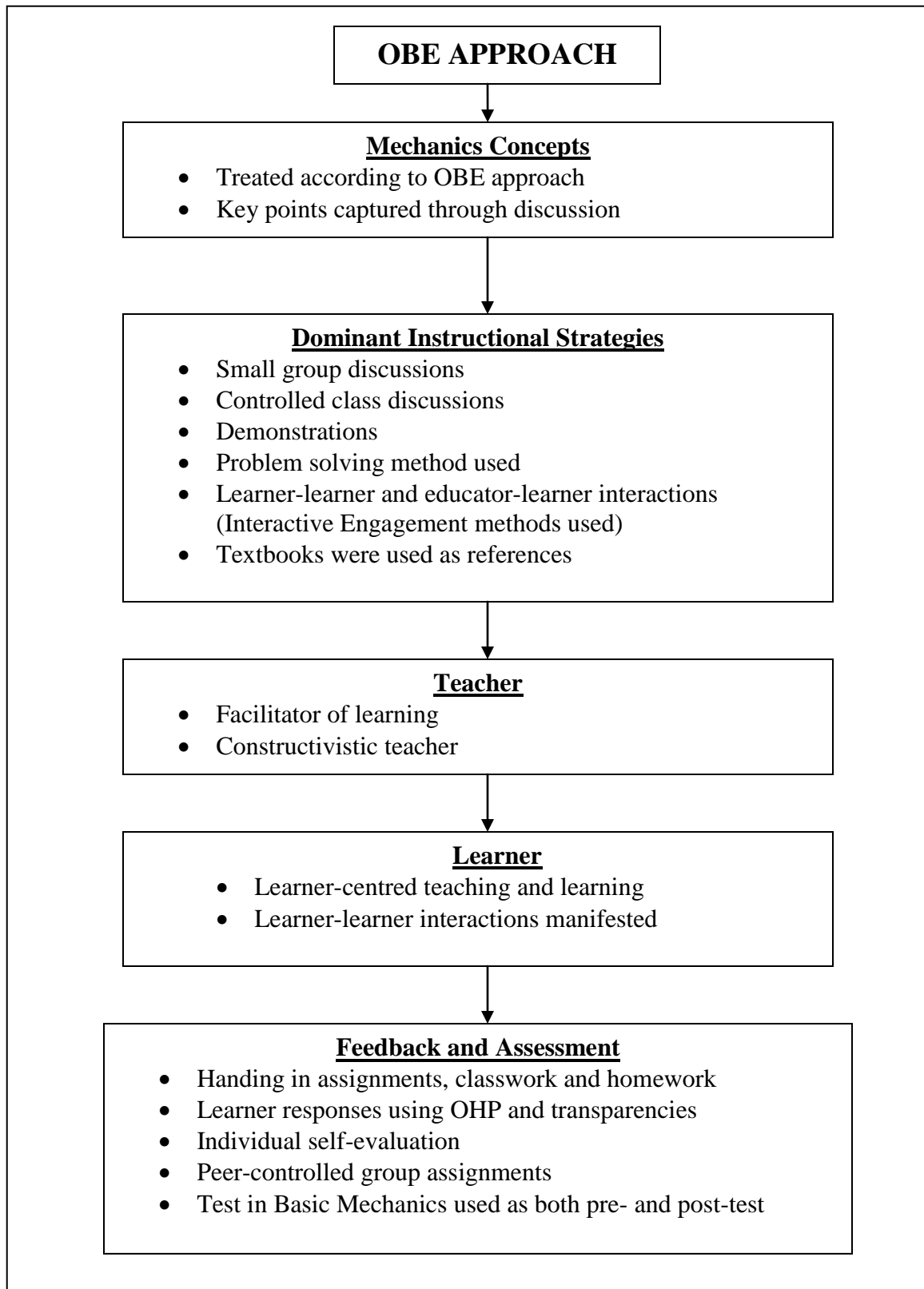


**Figure 2.6** Traditional Teaching Model followed in this study



## 2.7.2 THE OBE APPROACH TO TEACHING AND LEARNING

The OBE approach to teaching and learning is based on an emphasis on the attainment of specified outcomes. A Learning Outcome (LO) is a statement of an intended result of learning and teaching. It describes knowledge, skills and values that learners should acquire by the end of a particular learning programme, phase or education band (Department of Education, 2003:7). Spady (1994; as cited by Gravett & Geyser, 2004:144) describes outcomes as clear learning results that learners should be able to demonstrate at the end of significant learning experiences; they are what learners can actually do with what they know and have learnt. Spady (1994) further defines outcomes as actions and performances that embody and reflect learner competence in using content, information, ideas, and tools successfully. To name a few, there are Developmental Outcomes (DOs), Critical Outcomes (COs), Learning Outcomes (LOs), etc. The LOs for each learning area or subject are accompanied by the attendant Assessment Standards (ASs). By way of definition, ASs are criteria that collectively describe what a learner should know and be able to demonstrate at a specific grade (Department of Education, 2003:7). They embody the knowledge, skills and values required to achieve the learning Outcomes. ASs within each LO collectively show how conceptual progression occurs from grade to grade (Department of Education, 2003:7). Figure 2.7 shows the OBE teaching model that was followed in this study.



**Figure 2.7** OBE Teaching Model followed in this study

The knowledge of outcomes is important when one plans to design an OBE programme. When designing an OBE programme, Spady (1997: 26; 128 – 129; as cited by Gravett and Geyser, 2004:145) states that the following points should be kept in mind:

- Outcomes must drive learning programmes, not the reverse. Outcomes are the dog, and the programme the tail. Outcomes must be defined and developed first.
- Nothing inherently belongs in the programme unless it supports the demonstration of a complex outcome.
- Outcomes are about learning, and learning comes in at least four categories: principles, concepts and theories (knowledge); complex skills; moral learning (values); and psychological learning, for example, motivation and relationships (attitudes).
- Outcomes are learning results. They are what happen at or after the end of prolonged learning experiences. Outcomes should not be confused with programme details and test scores – they are not scores or grades, and not just content.
- Outcomes are clear demonstrations. They happen when learners actively do observable things with the information, skills, values and dispositions that they have acquired. Outcomes are developed by using powerful and significant “doing” and “action” verbs.
- Outcomes should be significant and have consequences far beyond the classroom.
- Focus should be on the kind of competencies that learners will need in their family, civic and career roles, and not on what is familiar about classroom instruction.
- Outcomes are complex and significant performance abilities, and not day-to-day tasks, assignments and tests (Spady, 1997:26; 128 – 129).

The above-mentioned points are an eye opener and they clear all sorts of alternative conceptions educators might have with regard to the concept 'outcome' as defined in OBE principles. One might confuse outcomes with test scores, learner achievement in day-to-day tasks and in assignments. In the same vein, Gravett and Geyser (2004:153) provide the following guidelines to be kept in mind when writing outcomes:

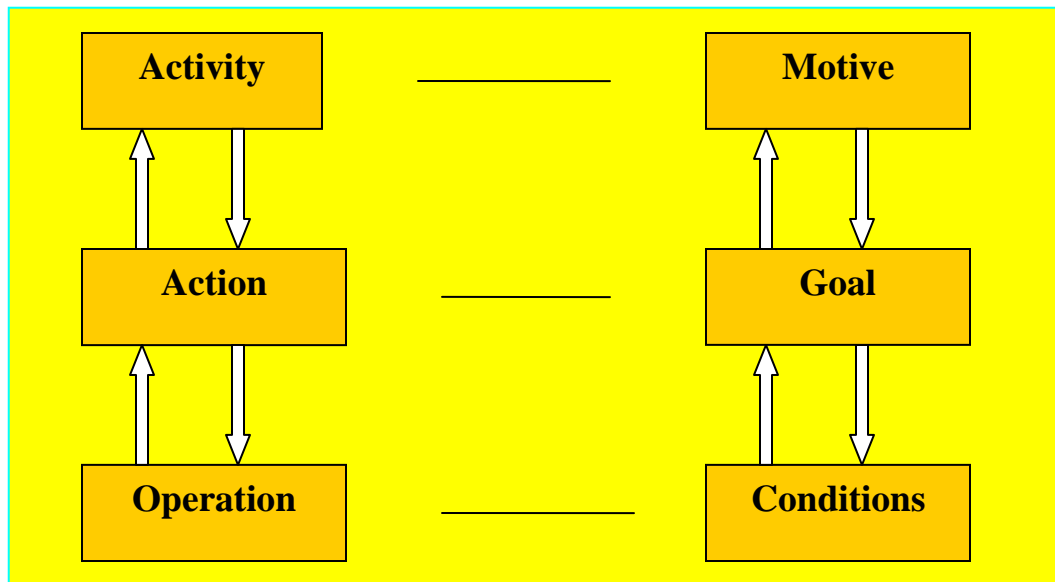
- Outcomes should provide a suitable balance between practical, foundational and reflexive competence. Practical competence refers to the demonstrated ability, in an authentic context, to consider a range of possibilities for action, to make considered decisions about which possibility to follow, and to perform the chosen action. Foundational competence refers to the learners demonstrated understanding of the competence knowledge and thinking that underpins the actions taken. Reflexive competence refers to the demonstrated ability to integrate and connect performances and decision making with understanding and with an ability to adapt to unforeseen circumstances, and to explain the reason behind such adaptation.
- They should describe observable, demonstrable and assessable performance(s).
- Verbs such as “understand” or “know” should be avoided. The curriculum designers should include the preface “The learner will ...”, followed by an action verb (A) +objects (O) + conditions (C), for example:
  - Describe (A) the educational value of children’s literature (O) in writing (C).
  - Portray (A) ideas and emotions (O) through movement (C).
- Outcomes should include the following aspects:
  - Who is to present the performance?
  - What performance is to be presented?
  - What conditions, if any, are to be provided for?
  - What constituents a minimally acceptable response?

- At what cognitive level is learning to occur, for example, memorisation, comprehension, integration, evaluation, and so on.
- Outcomes are statements that are unambiguous and readily understandable by both the learner and the lecturer or teacher.
- They should be in line with the relevant standards or qualification registered on the National Qualification Framework (NQF).

OBE also brings in the notion of the AT. As stated earlier, AT focuses on the achievement of a long-term goal – an outcome – through mediational means of tools within a community governed by rules and division of labour (Beauchamp, *et al*, 2009:267). Uden (2007:85) posits that AT also “focuses on understanding the human activity and work practices”. According to Nardi (1996) AT incorporates the notions of intentionality, mediation, history, collaboration and development. Jonassen and Rohrer-Murphy (1999:63) state that “the activity consists of a goal-directed hierarchy of actions that are used to accomplish the object – the task, actions, and operations that transform the object”. Jonassen and Rohrer-Murphy (1999:63) further maintain that an activity is the performance of conscious actions and consists of chains of actions and actions are chains of operations (Jonassen and Rohrer-Murphy, 1999). Furthermore, Jonassen and Rohrer-Murphy (1999:63) posit that

All operations are actions when they are first performed because they require conscious effort to perform. With practice and internalization, activities collapse into actions and eventually into operations, as they become more automatic, requiring less conscious effort. The reverse dynamic is also possible: operations can be disrupted and become actions.

The relationships among activities, actions, and operations are dynamic. Figure 2.8 shows the hierarchical nature of activities, actions and operations.



**Figure 2.8** Hierarchical nature of activities, actions and operations

[Source: Jonassen, D.H. and Rohrer-Murphy, L, 1999:63]

According to AT, learners (subject) functioning in contexts that can each be considered an activity system, progresses toward goals or objects that lead to an ultimate outcome (Beauchamp, *et al*, 2009). An example of an object for learners (subject) might be the writing of an assessment task, day-to-day tasks, assignments and tests. Guiding rules are given for the performance of the tasks. Riickriem (2010) avers that human activity is object-orientated and the term activity without object is senseless. In working toward this object, the learner uses mediational tools. For the OBE approach, tools might include library resources, computer, exercise books, etc. Learners, educators and parents form the community. Uden (2007:82) asserts that “learners have to continually strive to become an integral part of the community”.

Within an OBE environment, labour is divided as follows: Educators are responsible for the facilitation of learning, provide inputs and give feedback to learners. Learners complete worksheets, write assignment, tests, examinations,

etc. Parents support their children financially, materially as well as in doing homework or provide private tutors.

In this regard, the outcome is success in learning, attainment of specified outcome, practical competence (demonstrated ability) and conceptual understanding. Outcomes also can be viewed as knowledge, skills and values that learners should acquire at the end of a particular learning programme, phase, or education. Uden (2007:84) reports that

knowing as an activity that is co-determined by the individual and the environment. It is impossible to separate the learner, the material to be learned and the context in which learning occurs. Knowing always occur in a context.

According to Barab and Duffy (1999), 'knowing about' refers to an activity – not a thing. Uden (2007:84), further posits that “knowing about is reciprocally constructed within the individual – environment interaction. It is not objectively or subjectively created”. Barab and Krishner (2001) opine that knowing and contexts are co-constituted, and learning is fundamentally connected with and constitutive of the contextual particulars through which it occurs”.

OBE is committed to the following beliefs (Boschee & Baron, 1993:3; Van der Horst & McDonald, 1997:7; as cited by Mda & Mothata, 2000: 31):

- *All learners can learn successfully.* Without a commitment to the high expectations for successful learning for all learners, regardless of their background, age, learning style, previous achievement, or other factors, education is not outcomes-based.
- *Success results in further success.* Without a common vision that every success experienced by a learner builds self-esteem and the willingness to strive for further success, education is not outcomes-based.

- *Schools create and control the conditions under which learners succeed.* Without a belief that schools are responsible for learner success by the way they set priorities and provide for their learners, education is not outcomes-based.
- *The community, educators, learners and parents share in the responsibility for learning.* Without partnerships, which treat all stakeholders as significant resources for every learner's success, education is not outcomes-based.

This means that all learners can learn successfully and continue to succeed provided schools create and control the conditions under which learners succeed. Learners will succeed continually provided the community, educators, learners and parents share in the responsibility for learning. According to AT, educators, learners and parents share the same object with the subject and hence are called the community (Uden, 2007). In the same way, Jonassen and Rohrer-Murphy (1999:64) assert that "the community consists of the interdependent aggregate (e.g., designers within the organisation, subject matter experts, designers within professional associations, customers) who share (at least to some degree) a set of social meanings". In this regard, subject matter experts may refer to subject advisors and/or educators and customers may refer to learners and/or parents. Learners (subject) do assessment tasks (object) to achieve the objectives (outcome) of assessment.

#### **2.7.2.1 The Relationship between OBE and NCS**

The NCS curriculum is outcomes-based and it is driven by the LOs and the ASs. Physical science has three (3) learning outcomes to be achieved after the completion of the FET band, that is, after grade 12. Therefore, it is not possible to systematically study the NCS for physical science without locating it within the principles of OBE. The education system in South Africa has experienced a total transformation since the publication of the Policy Framework for Education and Training in January 1994 (ANC, 1994). In this document, among other things, goals were formulated for the education and training sectors. These goals reveal



the general political thinking pattern within which the choice of OBE was made (Bamps, Cronje, Elen & Thoka, 1998). Further, the Constitution of the Republic of South Africa (Act 108 of 1996) provided a basis for curriculum transformation and development in the country. As the NCS Grades 10 – 12 (Department of Education, 2003:2), points out:

OBE forms the foundation for the curriculum in South Africa. It strives to enable all learners to reach their maximum learning potential by setting the learning outcomes to be achieved by the end of the education process. The National Curriculum Statement (NCS) builds its learning outcomes for grades 10-12 on the Critical Outcomes (CO's) and Developmental Outcomes (DO's) that were inspired by the Constitution and developed through democracy. (Department of Education, 2003:2):

According to Sieborger and Macintosh (2004:33), “outcomes-based education is an approach to teaching, training and learning which stresses the need to be clear about what learners are expected to achieve”. They further state that “outcomes-based education is a learner-centred, result-oriented approach based on the belief that all learners can learn and succeed” (Sieborger & Macintosh, 2004:33).

William Spady (1994:8), who is seen as the father of OBE, highlights the viewpoint that what and whether learners learn effectively is more important than when and how they learn something. In OBE, “it is important to ensure that all learners will gain the necessary knowledge, skills and attitudes or to be successful lifelong learners, who will fulfill meaningful roles in real life, in and out of school” (Maree & Fraser, 2004:4). With regard to OBE, Spady (1994:9), formulated three assumptions:

- All learners can learn and succeed, but not on the same day in the same way.
- Successful learning promotes even more successful learning.

- Schools control the conditions that directly affect successful school learning.

The three assumptions serve as the rationale for the actual implementation of OBE, guided by its four principles (Spady, 1994:11-20; Spady & Marshall 1991:67). According to Spady, there is no one model for OBE, but OBE's purposes will be achieved if educators apply the following four principles consistently, systematically, creatively and simultaneously:

- Clarity of focus on culminating exit outcomes of significance.
- Expanded opportunity and support for learning success.
- High expectations for all to succeed.
- Design down from one's ultimate, culminating outcomes.

*Clarity of focus:* According to this principle, the whole curriculum is geared towards what the learners must be able to demonstrate at the 'real' end – that is, at the end of their schooling or university education – before they go on to fulfill their real-life roles in the world. More specifically, this principle gives a clear picture to the educator of the type of learning the learner must demonstrate in executing a performance. The overall focus on critical outcomes in South Africa gives the OBE system a very clear purpose and direction (Maree & Fraser, 2004:5).

*Expanded opportunity:* Educators must provide more than one opportunity to learners, if they are not successful, to demonstrate important learning. Rigid time frames and schedules must not restrict learning, although there must be limits to every expanded learning opportunity. The application of this principle also implies that educators must change their teaching methods to ensure successful learning for all. Expanded opportunity further implies that the same standards apply to all learners and that there will be no restriction on the number of successful learners. Furthermore, all learners must have the opportunity to be

exposed to a meaningful curriculum, quality learning experiences and multiple resources (Maree & Fraser, 2004:5).

*High expectations:* Learners must be exposed to challenges on a higher level that will raise the standard of expected levels of performance for successful learning. Higher expectations require that no restrictions be placed on the number of learners that can be successful. Normative referenced assessment, where a learner is compared with the performance of a group, must be replaced by criterion referenced assessment, where every learner performs against pre-set criteria (Maree & Fraser, 2004:5).

*Design down:* In designing and planning a curriculum at a micro level, that is, a learning experience and/or a learning programme, the educator must start with the culminating outcomes and then design back towards the enabling outcomes and the discrete outcomes. In other word, the designing-down process starts with what learners should be able to do at the end of their official learning experience and ends with what must be learnt today (Maree & Fraser, 2004:6).

In the South African context, the designing-down process must start with the critical outcomes, which are broad, generic and cross-curricular, and refer to real-life roles. The next step will be to design down towards the key building blocks on which the critical outcomes depend, namely, the specific/learning outcomes and the lesson outcomes. The last step in the designing down process is to determine which developmental (discrete) outcomes will enhance and support the performance of the critical outcomes, and to include them in the development of the learning experiences and/or programmes (Maree & Fraser, 2004:6). According to Spady (1994:53):

Specific content and skills are important in OBE because the golden rules of design down require that educators build into their curricula both the knowledge and competence bases that are critical for learners to develop and ultimately apply (omit unimportant knowledge and skills).

The main pedagogical attributes of OBE according to Imenda (2002:13) are:

- To promote active learning (physically and mentally);
- Learners to be assessed on an on-going basis;
- To promote the development of critical thinking, reasoning, reflection and action;
- To promote integration of knowledge (of education and training);
- Learning to be made relevant and connected to real life situations;
- Learning to be learner-centred, teacher to function as facilitator (use of group work, team work and other active learning approaches emphasized);
- Learning programmes to serve as guides that allow teachers to be innovative and creative in planning lessons and other learning activities;
- Learners to be afforded an opportunity to take responsibility for their learning, and should be motivated by constant feedback and affirmation of their worth;
- Emphasis to be placed on outcomes in terms of what the learner becomes and understands;
- Curriculum implementation should allow for flexible time frames which provide for learners to work at their own pace; and curriculum implementation should allow for inputs from the wider community.

#### **2.7.2.2 Instructional Approaches in Outcomes-Based Education**

According to Maree and Fraser (2004:10), “there are different views worldwide regarding outcomes based education”. They further state that, “OBE practitioners position themselves on a continuum between a behaviourist and a constructivist point of view”. According to Spady and Marshall (1991:8-71), “theory describes three outcomes-based approaches in practice, the traditional approach, the transitional approach and the transformational approach”.

*The Traditional Approach:* According to Maree and Fraser (2004:12):

In this approach, certain aspects of the curriculum are selected by the educator to form the basis of a new curriculum. The outcomes formulated

are synonymous with traditional and content-dominated sections, but do not relate to real-world demands and real-life experiences. The context in which learning takes place is bound to the classroom and the school. This approach is rarely driven by a framework of exit outcomes, but is rather a strive towards an academically competent learner. This approach tends more towards the behaviourist side on the continuum, and the outcomes in this approach are referred to as traditional outcomes (Maree & Fraser, 2004:12).

*The Transitional Approach:* According to Maree and Fraser (2004:12):

In this approach, outcomes of significance are defined to address higher-order competencies that are essential in all life and learning settings. The focus in this approach is on what is essential for learners to know, be able to do and be like in order to be successful in life after school. The outcomes in this approach focus on higher-order competencies such as critical thinking, good communication, technological application and problem solving.

*The Transformational Approach:* According to Maree and Fraser (2004:12):

In the transformational approach, none of the existing curriculum and/or schooling is taken as a given and nothing is untouchable. The outcomes in this approach are constructed in terms of real-life roles that competent citizens must fulfill in real life.

Spady and Marshall (1991:70) state it as follows:

When viewed from this future-oriented, life-role perspective, success in school is of limited benefit unless learners are equipped to transfer that success to life in a complex, challenging, high-tech future. Our prevailing, century-old, Industrial Age curriculum structure and delivery model lack credibility and capacity to generate these kinds of results.

### **2.7.2.3 Outcomes**

In the South African context, the word outcome is broadly used as an inclusive term. According to Maree and Fraser (2004:14), the word “refers to everything that has been learnt, including social and personal skills, learning how to learn concepts, knowledge, understanding, methodologies, values and attitudes”.

Spady (1994:49) describes outcomes as:

...the learning results we desire from learners that lead to culminating demonstrations. These results and demonstrations occur at or after the end of significant learning experiences; hence the term ‘culminating’. This means an outcome is not a collection or average of previous learning experiences, but a manifestation of what learners can do once they have had and completed all of those experiences. Outcomes are not simply the things learners believe, feel, remember, know, or understand, but instead, outcomes are what learners actually can do with what they know and understand.

However, the National Department of Education (1997:25), outcomes are seen simply as “the end products of a learning process.”

According to Maree and Fraser (2004:14), outcomes should be meaningful to learners in the sense that:

- Learners will remember and apply them long after a particular curriculum episode has ended.
- They will truly be important in fulfilling learners’ future life roles as citizens of their country and the world.

#### **2.7.2.3.1 Types of Outcomes**

According to Spady (1994:18), “outcomes are categorized into three main groups namely culminating outcomes, enabling outcomes and discrete outcomes”.

- Culminating outcomes: The meaning of the word ‘culminate’ is to reach the highest point. Culminating outcomes define what all learners must be

able to do at the end of an official learning experience. All learners are exposed to new learning experiences as they proceed through life and will be challenged with a next highest point at a next level. So within the context of outcomes, there is no fixed highest point and the expression of achieving an outcome must be seen within this context. Culminating outcomes are synonymous with exit outcomes, and can be defined for a whole education system, a qualification or a learning programme (Spady, 1994:18)

- Enabling outcomes: Enabling outcomes are the key building block on which culminating outcomes depend. Enabling outcomes contribute in an interdependent and integrated manner towards learners' ultimate performance success, and are not separate building blocks that are stacked on one another until a culminating outcome is reached (Spady, 1994:18).
- Discrete outcomes: Discrete outcomes are curriculum details that are 'nice to know' but not essential to a learner's culminating outcomes (Spady, 1994:18).

The National Department of Education defines two groups of outcomes, namely critical (essential) outcomes and specific outcomes. These outcomes are prescribed by the Department of Education at national level and encourage a learner-centred and activity-based approach to education (Maree & Fraser, 2004:14).

With regard to this study, critical and specific outcomes were considered in the learning programme for OBE intervention. These outcomes are based on problem-solving, teamship, self-responsibility skills, research skills, communication skills, technological and environmental literacy, and developing micro-vision. This study used small group (teamship) and class (communication skill) discussion as one of the main instructional strategies. Learners were also given opportunities to solve mechanics problems (problem-solving) that were

based on work, energy and projectile motion. All the LOs were also considered during the construction of the learning programme.

### **Critical Outcomes**

All education and training programmes in South Africa must adhere to the following critical outcomes, which underpin the Constitution and which were adopted by South African Qualification Authority (SAQA) (Maree & Fraser, 2004:15):

- Identify and solve problems and make decisions using critical and creative thinking (problem-solving skills);
- Work effectively with others as members of a team, group, organisation and community (teamship);
- Organise and manage themselves and their activities responsibly and effectively (self-responsibility Skills);
- Collect, analyse, organise and critically evaluate information (research Skills);
- Communicate effectively, using visual, symbolic and/or language skills in various modes (communication skills);
- Use science and technology effectively and critically showing responsibility towards the environment and the health of others (technological and environmental literacy); and
- Demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation (developing micro-vision).

The above-mentioned outcomes culminate in knowledge, skills, attitudes and values. For this reason, Maree and Fraser see South Africa's critical outcomes as synonymous with Spady's culminating outcomes. Critical outcomes also refer to real-life roles, as is the case with culminating outcomes. Critical outcomes are broad, generic and cross-curricular; are linked to all fields of teaching and



learning; and are of key importance as a focus for both standard setting and curriculum development (Maree & Fraser, 2004:15).

### **Specific Outcomes**

Specific outcomes can be seen as synonymous with enabling outcomes. These specific outcomes are derived from the critical outcomes and are constructed in an interdependent and integrated way as building block to enable learners to achieve overall competence in a field, within context, at a given level and are thus the key to progress in learning. Specific outcomes were formulated within context for each learning area of the General Education and Training (GET) phase. These outcomes set up a framework for the knowledge, skills, attitudes and values that learners need to know, understand and be able to demonstrate at the end of a learning experience (National Department of Education, 1997:26).

### **Developmental Outcomes**

SAQA has also proposed five additional developmental outcomes that contribute to the full personal development of each learner, as well as social and economic development at large. These developmental outcomes can be seen as discrete outcomes and are thus 'nice to know'.

According to the Department of Education (2003:2), the Developmental Outcomes (DOs) require learners to be able to:

- Reflect and explore a variety of strategies to learn more effectively (learning skills);
- Participate as responsible citizens in the life of local, national and global Communities (citizenship);
- Be culturally and aesthetically sensitive across a range of social contexts (cultural and aesthetic understanding);
- Explore education and career opportunities (employment seeking skills); and
- Develop entrepreneurial opportunities (entrepreneurship).

## **Learning Outcomes**

In the Revised National Curriculum Statement (RNCS) for the General Education and Training (GET) band, specific outcomes have been replaced by learning outcomes. Learning outcomes are also derived from critical outcomes and developmental outcomes. Learning outcomes are a description of what (knowledge, skills, attitudes and values) learners should know, demonstrate and be able to do at the end of a specific phase and can also be seen as enabling outcomes. Learning outcomes do not prescribe content or method, and have also been formulated at national level (National Department of Education, 2002:5).

## **Lesson Outcomes**

Lesson outcomes are constructed by educators and denote a description of what learners should know, demonstrate and be able to do at the end of a specific learning experience (lesson). Lesson outcomes can also be seen as enabling outcomes (Maree & Fraser, 2004:16).

Outcomes can be classified in categories according to:

- Operational functions (e.g. culminating outcomes, enabling outcomes, discrete outcomes);
- Curriculum scope (e.g. lesson outcomes, programme outcomes);
- Competency complexity (e.g. traditional outcomes, transformational outcomes);
- Content (e.g. lesson outcomes); and
- Time reference (e.g. qualification outcomes at universities) Spady, 1994:59).

Learning and assessment are the two sides of the same coin. Assessment is essential to gauge the effectiveness of the approach used in the teaching and learning environment.

#### **2.7.2.3.1 Outcomes-Based Assessment**

Assessment in the NCS is an integral part of teaching and learning. For this reason, assessment should be part of every lesson and teachers should plan assessment activities to complement learning activities. In addition, teachers should plan a formal year-long programme of assessment. Together, the informal daily assessment and formal programme of assessment should be used to monitor learner progress through the school year (Department of Education, 2005:1)

Outcomes-based Assessment (OBA) largely implies individual assessment based on the teacher's observation of an authentic task performed by the learner. As an integral part of learning, assessment involves attention to four concerns, namely: "Clear teaching and learning aims; motivation; previous experience and present abilities; and effective tasks and flexible teaching methods" (Education Department, 1991:12).

In OBE, the emphasis in assessment is on continuous diagnostic assessment of the learner's work over a period of time, rather than on performance in a high-stake, one-off examination or test. This approach to teaching and learning is aimed at ensuring success through intervention that will support the learner in the accomplishment of clearly stated outcomes and instructional interventions appropriate for the learner's stage of development. Thus, the methods teachers use to assess students' competences can reinforce a way of thinking about science.

In its simplest form, "assessment refers to collecting data about what learners understand and can do, evaluating those data, and making decisions based on that evaluation" (Dougherty, 1997:29). It is further stated that "if, however, teachers use assessment data only to inform students, their parents, or the school administration of what students know, then much of the power of assessment as a learning tool is lost" (Dougherty, 1997:29). In addition,

Dougherty (1997:29) states that “teachers should use assessment in two equally important ways: (a) to evaluate periodically students’ cumulative knowledge and understanding, a process known as summative assessment; and (b) to evaluate continually students’ progress in learning, a process known as formative assessment.” All teachers are familiar with summative assessment, the results of which are reflected in student report cards, but few pay much attention to formative assessment, which has the potential to drive changes in teaching that can improve students’ conceptual learning drastically (Dougherty, 1997:29). In addition, the emphasis on learning through assessment mitigates the perception that tests are tricks and places a greater responsibility on students for directing their own learning (Stiggins, 1994).

Physical science focuses on investigating physical and chemical phenomena through scientific enquiry. By applying scientific models, theories and laws, it seeks to explain and predict events in our physical environment. The focus of most student assessment should, therefore, be formative, to encourage and guide continual learning. This means that daily assessment should be used to give feedback to learners as to their strengths and weaknesses and help them to develop strategies to improve their learning. It should also be used to help the teacher teach more effectively by developing a better learning programme which speaks to the needs of the learners – as well as their stages of intellectual development (Department of Education, 2005:7).

According to the Department of Education (2005:7), assessment tasks should focus on the following in an integrated manner:

- The learner’s ability to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific and technological, environmental and everyday contexts (Learning Outcome 1).
- The learners’ demonstration of enquiry skills, like planning, observing, collecting data, comprehending, synthesising,

generalising, hypothesising and communicating results and conclusions. The learner's ability to state, explain, interpret, evaluate and apply scientific and technological knowledge in everyday context (Learning Outcome 2).

- The learner's ability to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development (Learning Outcome 3).

The requirements of OBE are that student assessment procedures should, of necessity, reflect the following attributes (Jacob, Luckett & Webbstock, 1999:122-123):

- Assessment should be based on human interaction and judgment;
- Student capabilities should be seen as a social construct;
- Educators should be aware of the possibility of multiple realities, hence multiplicity of possible competencies and capabilities (This contradicts the practice and notion of setting the same educational outcomes for everybody in a given programme of study);
- Educators should see intelligence/capability as being culturally and contextually dependent;
- Educators should use both formative and summative assessment to inform the instructional process, and ascertain the degree of attainment of intended outcomes;
- All aspects of learning (understanding, skills and values) should be assessed in an integrated way;
- Assessment should cover both the processes and products of learning;
- Assessment should concern itself with the use and application of knowledge, understanding, values and skills;
- Assessment should be continuous, and should cover internal and external issues pertinent to intended learning outcomes;

- Assessment should be made part of the instructional process;
- A diversity of assessment procedures and tools should be used, e.g. projects, portfolios, self-assessment and peer assessment; written and verbal;
- Both qualitative and quantitative descriptions/ measures of performance should be used;
- Learning outcomes to be made explicit to learners; and
- Cultivation of a culture of life-long learning.

In OBE, assessment should be done daily and continuously since it cannot be separated from teaching and learning.

An outcomes-based system relies on a clear set of learning outcomes on which the curriculum, learning facilitation and assessment are focused. The outcome provides the facilitator with a starting point and focus, in relation to the curriculum, instruction and assessment (Betts & Smith, 1998). Similarly, outcome is shared with, and explained to, the learners on a continuous basis to ensure that the 'transparency' philosophy on OBE is fully realised (Schwarz & Cavener, 1994:328; Spady, 1994:9). In addition, OBE focuses on the philosophy of success for all learners with learners exiting successfully from the education system (Spady, 1994:9). Thus, Barr and Tagg (1995:11) maintain that a learning environment is created that is challenging, co-operative, collaborative and supportive. This creates a win-win situation where success in learning is attainable. The learner experiences success in learning by attaining outcomes that promote more success and lead to expanded opportunities in learning (Schwarz & Cavener, 1994:329; Spady, 1994: 9). The expanded opportunities for learners to attain outcomes in the OBE approach consequently encourage the high expectations of learners (Schwarz & Cavener, 1994:328).

To be successful in practising a profession, Spady (1994:55) argues that the learner requires specific knowledge and then integrates and applies the

knowledge within a specific content. This feature of the OBE approach, namely that key life skills should link to experiences in the real world, makes it very relevant to learners, their families and future employers (Spady, 1994:55). It therefore encourages learners to demonstrate more complex and long-lasting learning, compared to traditional assignments and pencil and paper tests (Spady, 1994:55).

The assessment process must be conducted to contribute to the learning experience of the learner (Spady, 1994:103). To contribute to the learning experience and to provide the learner with a greater chance to succeed, Cunningham (2002:258) adds that attention should be paid to providing better feedback on assessment and on providing remediation activities to learners. In the same vein, Bligh (2001: 74) mentions that assessment should discover what the learner has learnt, rather than what has been taught. Accordingly, assessment therefore should reflect as closely as possible the actual tasks performed. This is what constitutes authentic or performance assessment (Brown, Race & Smith, 1996:74; Bligh, 2001:312). Ben-David (1999:23) argues that performance assessment and OBE are closely related paradigms because these approaches are bound by simple educational principles, namely that assessment methods should match the learning modality. Assessment in the OBE approach is a continuous process based on a holistic and integrated approach to facilitate learning. Assessment should therefore be conducted in a manner to enable progress and academic development of the learner.

### **Principles of Outcomes-Based Assessment (OBA)**

The following important concepts must be first explained: *assessment approaches*, *assessment strategies* and *assessment agents*. The term *assessment approach* is used in this study to represent diverse approaches including categories of classification; forms of assessment, such as norm-referenced and criterion-referenced assessment; formative assessment, summative assessment, among others. The term *assessment strategy* is used in

this study for different methods, types or tools of assessment. Clark (1996:336) argues that “strategies are conceived at the level of organization and structure”. He continues to say that “tasks are conceived at the level of activities”. There are many activity systems involved in OBA. Examples are well-known traditional assessment instruments or tools such as portfolios, journals, and activity checklists (Maree & Fraser, 2004:48-49; as cited by Mchunu, 2009:74). According to the AT, portfolios, journals, and activity checklists are the mediating tools. Jonassen and Rohrer-Murphy (1999:66) opine that “activity always involves artifacts (instruments, signs, procedures, machines, methods, laws and forms of work organization)”. Assessment agents involve the actions of the interested parties and may include educators and learners, policy makers and academics, as well as parents and the community (Maree & Fraser, 204:49; as cited by Mchunu, 2009:74). According to the AT, the assessment agents form the community. By way of description and as stated earlier, the “community is made up of one or more people sharing the same object with the subject” (Uden, 2007:85). Jonassen and Rohrer-Murphy (1999:66) further posits that “activities are socially bound. So, any activity system can be described only in the context of the community in which it operates. The community negotiates and mediates the rules and customs that describe how the community functions”. There are rules followed when preparing as assessment task and learners (subjects) also follow rules or instruction when doing the task.

According to Maree and Fraser (2004:51-53) assessment strategies used in the outcomes-based assessment are:

*Objective tests* (selected response tests or ‘pen and paper’ tests), requiring structured learner responses. Major types include supply type (short answer and completion), and selection type (multiple choice, true/false and matching).

*Essay tests*, requiring responses that are either restricted-response tests or extended-response tests. Essay questions provide the freedom of response that is needed adequately to assess the ability of learners to demonstrate reasoning



abilities and to apply skills in order for educators to interpret complex achievement.

*Personal communication:* This strategy of assessment may take a variety of forms, including instructional questions and answers, oral examinations, interviews and journals (Maree & Fraser, 2004).

*Performance-based assessment (performance assessment):* This strategy requires the demonstration of skills or proficiency through creating, producing or doing something, often in a setting involving real-world applications. The emphasis is on doing, not merely on knowing, on process as well as on product. This strategy is mostly widely used to assess abilities of learners under given conditions and instructions (Maree & Fraser, 2004).

Assessment in OBE is outcomes based. To ensure that the assessment is in line with the principles of the NCS and that there is equality of opportunity and no discrimination or bias in respect of gender, race, disability or even social class, the following principles as outlined by Prinsloo and Van Rooyen (2003:34-36):

*Transparency:* Something is transparent when it is clear to everyone who uses it. So, the assessment process must be clear and open to the learners. A learner must have a right to question and appeal the assessment procedure.

*Validity:* Assessment must assess what it claims to assess. Educators as assessors should be fully aware of what is to be assessed as indicated by the unit standard or learning programme, the performance outcomes and the assessment criteria. Evidence is collected from activities and tasks that can be clearly related to the capability or performance outcomes specified for learning programme or unit standard.

Evidence should demonstrate that performance outcomes have been met and is gathered in an integrated fashion within the context of work to be assessed. Assessment procedures, methods, instruments and materials have to match what is being assessed. These assessment procedures, methods, instruments and materials are mediating tools that used to assess the learner (subject). An

assumption of activity theory is that tools mediate or alter the nature of human activity and when internalised, influence human's mental development (Jonassen & Rohrer-Murphy, 1999). Kaptelinen (1996:10) argues that all "human experience is shaped by the tools and sign systems we use". The purpose of assessment cannot be achieved without the assessment tools. Just as artefacts or tools (assessment instruments) mediate the relationship between subject (learner) and object (assessment), rules (assessment principles) mediate the relationship between subject and community (educators and learners) (Uden, 2007). In the same way, Jonassen and Rohrer-Murphy (1999:67) assert that

Just as activity can be understood by comprehending the tools and signs that mediate it, the nature of a tool can be understood only in the context of human activity – by looking at the way that people use it, the needs it serves, and the history of its development. Tools are changed by the ways in which they have been used... tools are a reflection of their historical development – they change the process and are changed by the process.

The kind and amount of evidence required should determine the assessment that should be used and selected. The assessment should be within the parameters of what is required, not less or more than required by the unit standard or learning programme. According to Prinsloo and Van Rooyen (2003:35), in order to achieve validity in assessment, assessors should:

- State clearly what outcome(s) is (are) assessed;
- Use an appropriate type or source of evidence;
- Use an appropriate method of assessment; and
- Select an appropriate instrument of assessment.

### **2.7.2.3.3 Continuous Assessment in OBE**

Continuous assessment (often abbreviated as CAS) is an assessment strategy that bases decisions about learning on a range of different assessment activities and events that happen at different times throughout the learning process (Department of Education, 2005). In this regard, CAS involves assessment activities that are spread throughout the year, using various kinds of assessment methods such as tests, examinations, projects and assignments to name, but a few. Ideally, the different pieces of evidence that learners produce as part of continuous assessment are compiled into a portfolio (Department of Education, 2005:12; as cited by Mchunu, 2009:78).

Consequently, CAS through informal daily assessment and the formal programme of assessment should be used to:

- Develop learners' knowledge, skills and values;
- Assess learners' strengths and weaknesses;
- Provide additional support to learners;
- Revisit or revise certain sections of the curriculum; and
- Motivate and encourage learners (Department of Education, 2005:1; as cited by Mchunu, 2009:78)

According to Roth (2003:40),

“assessment and evaluation of student achievement is one of the fixed and unavoidable – for both teacher and student – elements of the school and of instruction”. Roth (2003:40) further states that “ assessment and evaluation are also important for the individual teacher for the purpose of diagnosing pre-suppositions in learning and the results of learning on the part of students, for advising students and parents, and last but not least, for evaluating and checking the effectiveness of the teacher's instruction”.

Within the context of South Africa's OBE, CAS occupies the centre piece of learning.

In a critical analysis of the underlying philosophical underpinnings of OBE, the following four philosophical have been identified:

- Behaviourism;
- Social reconstructionism;
- Critical theory; and
- Pragmatism (Steyn and Wilkinson, 1998:203-205).

The OBE is based on strong behaviourist assumptions can be seen in the way Spady (1994) defines outcomes.

With regard to the critical theory, “the key focus areas in the philosophy of critical theory are the change and emancipation of societies and individuals from being regulated and indoctrinated, towards being critical and questioning” (Steyn & Wilkinson, 1998:204). Learning programmes should promote that the learners’ ability to think critically. One of the national critical outcomes, as formulated by South African Qualifications Authority (SAQA), is the following: “Collect, analyse, organise and critically evaluate information” (Republic of South Africa, 1997:13).

It is worth mentioning that OBE has many advantages. Van der Horst and McDonald (1997:14-16) list the following advantages:

- Learners know what is expected of them, and they are able to assess their own progress.
- OBE provides the learner with greater learning support than in the past practices. Co-operative learning techniques, self- and peer-assessment are only a few examples of the learner support that should be an integral part of learning.
- Permanent failure is eliminated. Learners who do not achieve the required standard are granted further opportunities to do so.
- Rote learning is reduced. Understanding of content is more important than merely being able to reproduce knowledge.

- The absorption of miscellaneous, discrete facts is eliminated. Understanding of context is emphasised.

It is however also noted that OBE has its own limitations, problems, and/or disadvantages, as reflected by literature. Van der Horst and McDonald (1997:16-19) have identified the following problem areas:

- Outcomes which define what all learners should master often indicate behaviours and values that are vaguely worded, and are often largely associated with emotions (attitudes and values). Many of these do not focus on core academic content. A sound content base is always a prerequisite for critical thinking and problem solving.
- The question of whose values are taught in school seems to be a thorny issue. Parents might not agree with the values and attitudes promoted in the OBE. It is not easy to achieve public consensus in a country as multicultural as South Africa.
- Some critics of OBE believe that schools using an OBE approach will have to lower their standards to the lowest denominator since not all learners have the same potential to learn to the same high standards. OBE holds back the gifted learners and slower learners retard the progress. There is thus a general concern about standards.
- In terms of resources, it has been suggested that OBE favours those privileged schools with extensive resources, and that it creates a wider gap between privileged communities and historically deprived communities.

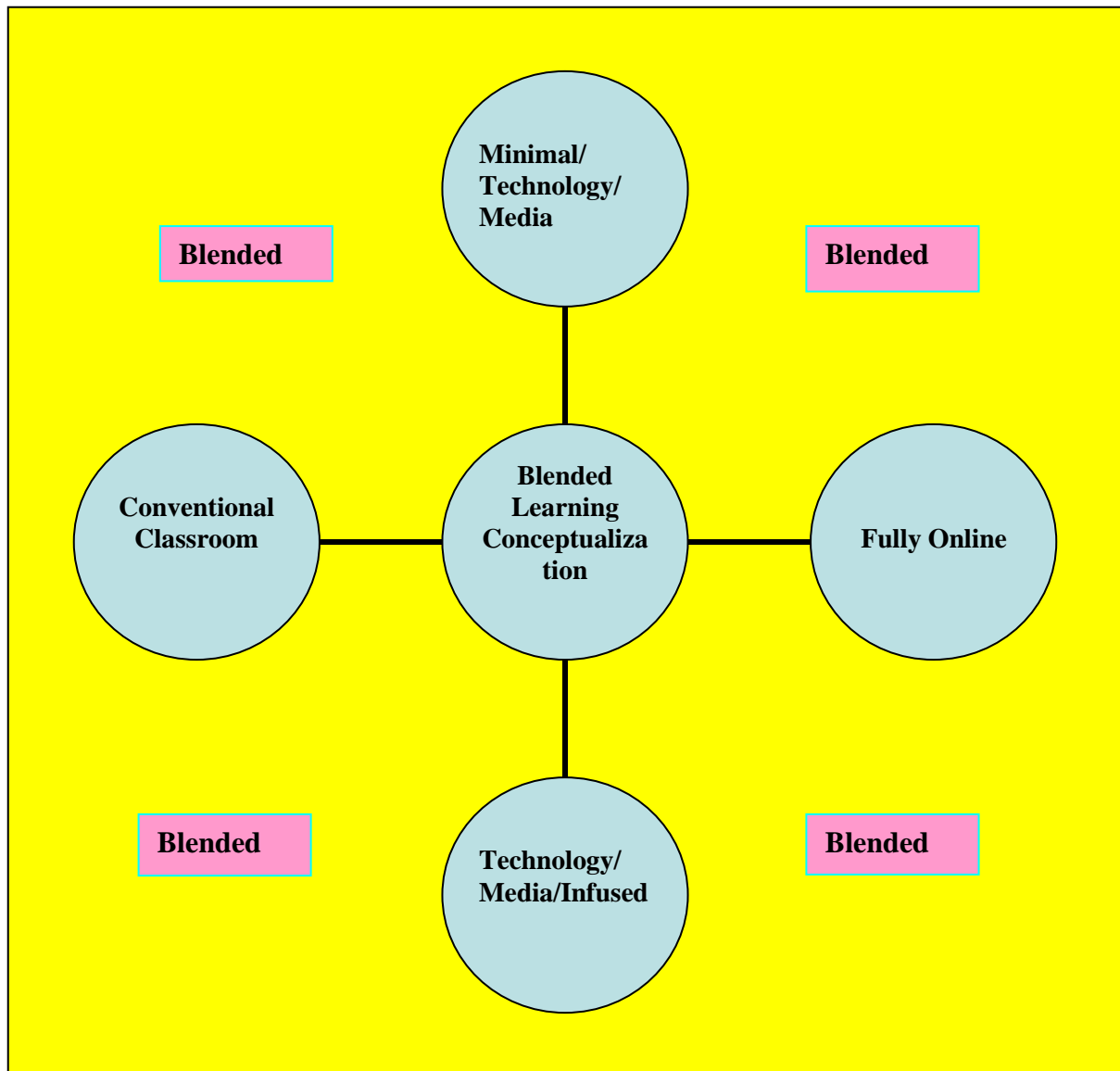
As a limitation, the effectiveness of OBE depends mainly on teachers' ability to implement such an approach. Van der Horst and McDonald (1997:16) posit that OBE requires hard work, a lot of planning and sensitivity towards the learning process.

### 2.7.3 THE BLENDED APPROACH TO TEACHING AND LEARNING

According to Valiathan (2002) the term blended learning is used to describe a solution that combines several different delivery modes, such as collaboration software, Web-based courses, and knowledge management practices. Singh and Reed (2001:2) assert that “the original use of the phrase ‘Blended Learning’ was often associated with simply linking traditional classroom training to eLearning activities”. Valiathan (2002) further maintains that blended learning is also used to describe learning that mixes various event-based activities, including face-to-face classrooms, live e-learning, and self-paced learning. Picciano (2006) opines that blended learning is not one thing. It comes in many shapes, flavours, and colours. Picciano (2006:2) further maintains that

in one course, blended learning may be used to enhance the traditional lecture with electronic instructor notes, additional readings, and images of charts, graphs, or other handouts. In another course, online learning may be combined with face-to-face instruction so that rather than meeting in a classroom three hours a week, a course meets two hours per week with the third hour consisting of an online threaded discussion.

Furthermore, Picciano (2006:2) states that “in the broadest sense, blended learning can be defined or conceptualized as a wide variety of technology/media integrated with conventional, face-to-face classroom activities”. Figure 2.9 below shows a broad conceptualisation of blended learning as developed by Picciano (2006).



**Figure 2.9** Broad Conceptualisation of Blended learning

Source: Picciano, A.G., (February 9, 2005).

Picciano's (2006) definition as supported by Figure 2.8, eliminates certain forms of stand-alone media such as videotape, CD-ROM, or DVD that might be used solely in a face-to-face course. However, it would not eliminate these media if used in a course that had both an online and a face-to-face component (Picciano, 2006).

In the same way Rovai and Jordan (2004:1) describe blended learning as “a hybrid of classroom and online learning that includes some of the conveniences of online courses without the complete loss of face-to-face contact”. Their study examined the relationship of sense of community between traditional classroom, blended, and fully online higher education learning environments (Rovai & Jordan, 2004). With reference to the Activity Theory (AT), Rovai and Jordan (2004:1) suggest that “blended courses produce a stronger sense of community among students than either traditional or fully online courses”.

In the same way, Bonk and Graham (2006:219) define blended learning as “blended learning systems that combine face-to-face instruction with computer mediated instruction”. Saunders and Werner (2002) define blended learning as “learning that employs multiple strategies, methods, and delivery systems” and which combines the best features of online learning with the best features of classroom instruction (Troha, 2002). This implies that the blended approach accommodates all individual characteristics of learners in the learning environment. The Department of Education (2005:33) asserts that “learners have different styles of learning. Teachers must create as many opportunities as possible to expose learners to different learning strategies”. This is the way in which the Developmental Outcome Number 1 (DO 1) can be achieved. DO 1 requires learners to be able to “reflect on and explore a variety of strategies to learning more effectively” (Department of Education, 2003:2). The implication for learners is that they should engage in different learning strategies and can identify the most effective learning strategies in mastering physical science (Department of Education, 2005). Driscoll (2001) states that blended learning may be understood as to refer:

- To combine or mix modes of web-based technology (e.g., live virtual classroom, self-paced instruction, collaborative learning, streaming video, audio, and text) to accomplish an educational goal.



- To combine various pedagogical approaches (e.g., constructivism, behaviourism, cognitivism) to produce an optimal learning outcome with or without instructional technology.
- To combine any form of instructional technology (e.g., videotape, CD-ROM, web-based training, film) with face-to-face instructor-led training.
- To mix or combine technology with actual job tasks in order to create a harmonious effect of learning and working.

In the same way, Padayachee and Harding (2011) in their study defined the features of their blended model as a model that incorporates DVD technology, which offers an affordable and accessible option for the particular group of learners. They used DVD technology as an ingredient in their blended learning approach since it is easily available to learners and to the school they attend.

According to Singh and Reed (2001:1)

blended learning can be described as a learning program where more than one delivery mode is being used with the objective of optimizing the learning outcome and cost of program delivery. However, it is not the mixing and matching of different learning delivery modes by itself that is of significance, but the focus on the learning and business outcome.

In this regard, they propose to refine this definition to say:

Blended learning focuses on optimizing achievement of learning objectives by applying the “right” learning technologies to match the “right” personal learning style to transfer the “right” skills to the “right” person at the “right” time (Singh & Reed, 2001:2).

Embedded in this definition are the following principles:

- Focus is on the learning objectives rather than the method of delivery;

- Many different personal learning styles need to be supported to reach broad audiences;
- Each member brings different knowledge into the learning experience; and
- In many cases, the most effective learning strategy is “just-what-I-need, just-in-time” (Singh & Reed, 2001:2).

Research reveals that “putting these principles into practice can result in the radical improvements in the effectiveness, reach and cost-effectiveness of learning programs relative to traditional approaches” (Singh & Reed, 2001:2). The point is, blended learning may mean different things to different people. The above definitions illustrate the untapped potential of blended learning.

Bonk and Graham (2006:219) further claim that generally, people choose the blended learning for three reasons:

- Improved pedagogy,
- Increased access and flexibility, and
- Increased cost-effectiveness.

Ates, Turali and Guneyce (2008) indicate that traditional face-to-face learning environments are indispensable for social aspect of teaching and learning. However, internet-based asynchronous technologies such as e-mail, forum, listserv, blog, e-portfolio, webfolio, etc. can provide learners with more flexible and interactive learning environments independent from time and space. Also, synchronous technologies such as a chat, videoconferencing, instant messaging tools, etc., can enhance interaction between instructors and learners which may provide motivation for learning (Ates, Turali & Guneyce, 2008). Thus, educators should use various teaching strategies since in a class there are different learner characteristics with different learning styles. Imenda (2010:3) avers that blended teaching and learning “tend to be more effective – mainly because different learners learn best through different approaches”. Driscoll (2001) further claims

that using blended learning benefits the learner, the training staff and the organization's bottom line. Furthermore, Driscoll (2001) maintains that blended learning allows organizations to gradually move learners from traditional classrooms to e-learning in small steps making change easier to accept. It is therefore easy to develop the skills needed in learners by using blended teaching and learning.

#### **2.7.3.1 Relationship between Blended Approach and NCS**

Both the blended approach and NCS encourage interactive engagement of learners and collaboration. Blended approach builds on both the traditional and OBE approaches. Blended approach includes computer-mediated and online teaching and learning. On the other hand, NCS stresses small group or class discussion. Margaryan, *et al* (2004) state that blended learning is process-oriented rather than content-oriented. NCS is a curriculum that is not content-driven but process-oriented and outcomes-driven. In both the blended and the NCS the assessment is continuous.

#### **2.7.3.2 Instructional Approaches in Blended Teaching and Learning**

It has been stated in this chapter that blended learning is not one thing. It comes in many shapes, flavours and colours (Picciano, 2006). It is therefore defined by one who applies it as long as it is applied according to its description or definition. Picciano (2006) further posits that blended learning may be used to enhance the traditional lecture. Blended learning uses more than one delivery mode with an objective of optimizing the learning outcome (Singh & Reed, 2001) including the delivery modes used in the traditional and OBE approaches to teaching and learning. Depending on the description or definition by the one applying this approach, blended learning may include among other instructional approaches, DVD technology (Padayachee & Harding); Web-based environment using the TeleTOP system (Collis & Moonen, 2001); mobile technology (cellphones) (Uden, 2007); computer simulations (Jmoyiannis & Komis, 2001), e-learning (Margaryan, *et al*, 2004), computer animations, and so on.

Basically, in blended learning face-to-face contact is not completely lost (Rovai & Jordan, 2004). Thus, lecture or telling method, demonstrations, etc, are still in place in blended learning. Blended learning encourages collaboration. The study done by Ross (2011:1) on “from transformative outcome based education to blended learning”, reveals that “effective collaborative engagements among team members resulted in strengthened curricula with evidence of a reflective implementation of outcome focused course delivery”. Singh and Reed (2001) posit that collaborative learning implies a more dynamic communication among learners that brings about knowledge sharings. Blended learning also involves self-paced learning. Thus,

the blending of self-paced and collaborative learning may include review of important literature on a regulatory change or new product followed by a moderated, live online, peer-to-peer discussion of the material’s application to the learner’s job and costumes (Singh & Reed, 2001:2).

Picciano (2006:5) states that “pedagogical techniques such as reflective teaching practice, collaborative, self-pacing, and intensive writing may work better in online learning environments”. Thus, as stated earlier in this chapter, blended learning mixes various teaching modalities. Blended learning has no specific instructional strategy.

### **2.7.3.3 Outcomes in blended approach in Terms of Activity Theory (AT)**

According to AT, “an activity is undertaken by a subject using tools to achieve an object (objective), thus transforming into an outcome” (Uden, 2007:85). Uden (2007:84) further avers that “there are several techniques and tools that have been developed to support taking the context into account in the design of computer technologies”. According to Beauchamp, Jazvac-Martek and McAlpine (2009), AT focuses on the achievement of a long-term goal which is transformed

into an outcome. Thus, outcomes in terms of AT are achieved in the following way:

The long-term goal of completing a course (e.g. PhD) involves work toward the achievement of that outcome, through a central, conscious and goal-directed action, requiring engagement in a multitude or network of activity systems. Each system has components that interact in the achievement of an objective, or purpose for specific activity system (Beauchamp, *et al*, 2009:267).

Uden (2007) asserts that AT is a social and a cultural psychology theory. Thus, blended learning opens up the potential for children's group collaboration. Blended learning provides more equal opportunities for learners to initiate interactions (Winnips, 2001). Based on these statements, it appears that the blended approach also adheres to the following critical outcomes:

- Work effectively with others as members of a team, group, organisation and community (teamship);
- Communicate effectively, using visuals, symbolic and/or language skills in various modes (communication skills); and
- Use science and technology effectively and critically showing responsibility towards the environment and the health of others (technological and environmental literacy) (Maree & Fraser, 2004:14).

In blended learning students are expected to engage in online discussion in groups (Macdonald & Twining, 2002). In this way, students are given an online collaborative activity in which they are expected to work in small sub-groups in order to search for resources on the internet, and to reflect on their experiences of online collaborative working (Macdonald & Twining, 2002). Thus, a key aspect to the blended learning, "is the sharing of experiences related to the learning activity" (Margaryan, *et al*, 2004:265). They further opine that an organisation

can enhance the effectiveness of e-learning by blending technology with social interaction and collaborative learning, workplace-based activities with supervisor involvement and input from experienced facilitators (Margaryan, Collis & Cooke, 2004).

Janassen and Rohrer-Murphy (1999:62) describe the subject of any activity as “the individual or group of actors engaged in the activity”. In the case of the blended approach, the subject is the learner or learners in the whole classroom. The object of the activity is the physical or mental product that is sought. In this way, the object is acted upon by the subject (Janassen & Rohrer-Murphy, 1999:62). In this regard, the object with reference to the blended approaches is the achievement of the learning objectives. According to Uden (2007), tools can be physical or psychological. In this manner, the tools in blended approach are the technology or electronic resources (e.g. mobile technology, computer assimilations, etc.). The teacher or tutor or facilitator and the class of students form the community. With regard to the division of labour, teacher disseminates information to students, write notes on the chalk board with learners copying notes to their notes exercise books (face-to-face instruction). As a rule, learners are engaged in group discussion or collaboration. Students also write tests and examinations and the teacher marks and give feedback to students.

#### **2.7.3.4 Assessment in Blended Teaching and Learning**

Blended learning mixes different modes of teaching and learning, including computer-mediated learning, eLearning, networked environments, etc. This means it combines traditional, face-to-face instruction and OBE approaches. Therefore assessment in blended teaching and learning follow specific principles more especially for networked courses. In this regard, McDonald and Twining (2002) report three priorities for the design of assessment for an activity-based approach for the assessment of any constructivist pedagogy in a networked environment. These priorities are:

*Assessment must reflect course philosophy:* In line with constructivist principles, assessment should be aligned with the exercise of active learning.

*Assessment is essential in creating learning opportunities at critical points:* If the course is designed around learning activities, then it is important that students undertake those activities in order to engage with the learning process and derive benefit from the course.

*Assessment provides a vital opportunity for feedback, helping to complete the reflective learning cycle:* For online distant students, assessment is critical in providing a vehicle through which they receive formal feedback on their learning McDonald and Twining (2002:616-617).

With regard to assessment in the blended approach, assessment is done on a regular basis (Margaryan, *et al*, 2004) beginning the course with base-line assessment. Base knowledge is one of the key factors that is considered in blended teaching and learning (Singh & Reed, 2001:5). Base-line assessment is used by an educator at the beginning of a new set of learning activities in order to find out what the learner already knows and can demonstrate in order to decide what level of demands to build into the learning experience plan (Department of Education, 2001:14). Base-line assessment helps in the planning of activities and in learning programme development. The recording of base-line assessment is usually informal. According to Maree and Fraser (2004:49), this approach determines learner performance at the beginning of instruction to obtain an idea of the abilities and interests of the learners. They further state that

Assessment information such as test scores, observations of learner performance and learner involvement determines learner progress and level of understanding. Assessment that occurs prior to instruction is a valuable tool to facilitate instructional and planning activities, and also to direct subsequent assessments.

Baseline assessment helps to identify preconceptions, alternative conceptions held by learners in particular course as well as the conceptual difficulties experienced by learners. After baseline assessment, diagnostic assessment is also an essential form of assessment that helps to address learning difficulties.

*Diagnostic assessment* is assessment, which specifically focuses on finding out the nature and cause of learning difficulties, in order to providing appropriate remedial help and guidance (OBE assessment, 2001:14). Any assessment can be used for diagnostic purpose to discover the cause or causes of a learning barrier. Diagnostic assessment assists in deciding on support strategies or identifying the need for professional help. It acts as a checkpoint to help redefine the learning programme goals, or discover what learning has not taken place so as to put appropriate intervention strategies in place. As Maree and Fraser (2004:49), state “the aim of diagnostic assessment is to determine causes of persistent learning problems and to formulate a plan for remedial actions”.

*Formative assessment* is sometimes seen as being the opposite of summative assessment. It is conducted as the learning takes place and it is used to influence or inform the learning process.

Flanagan (1998:74), and Le Grange and Reddy, (1998:5), state that “any form of assessment that is used to give feedback to the learners is fulfilling a formative purpose”. Formative assessment is a crucial element of the teaching and learning process. It monitors and supports the learning process. All stakeholders use this type of assessment to acquire information on the progress of learners. Constructive feedback is a vital component of assessment for formative purpose (Department of Education, 2003:56). According to Maree and Fraser (2004:49), formative assessment monitors learning progress during instruction, and provides feedback to learners and educators concerning successes and failures.



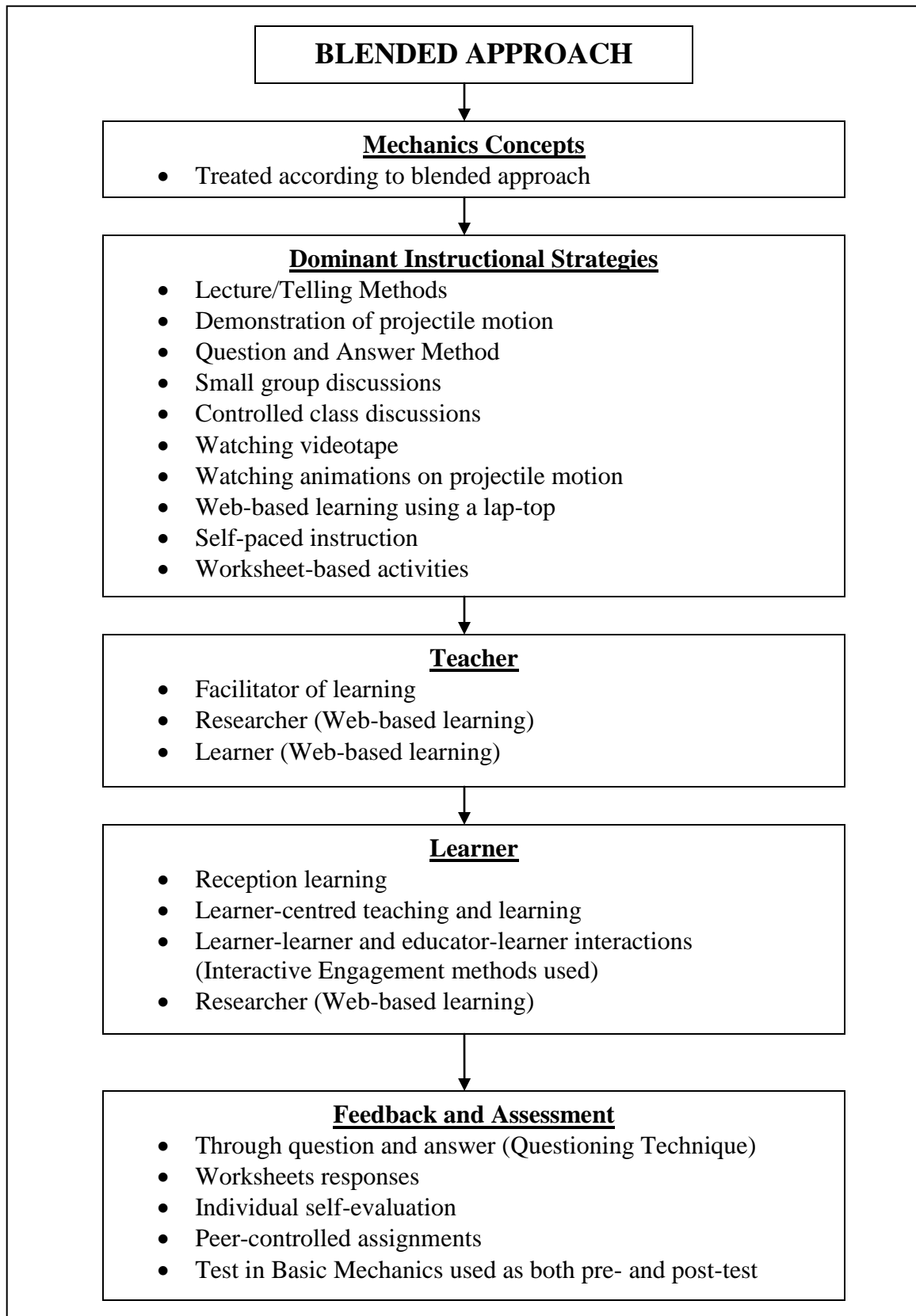
*Criterion-referenced assessment* refers' to testing in which learners' scores (results) are compared to a set standard. The scores are thus not compared to those of other learners or students, but to a given or set criterion or standard or performance. Criterion-referenced tests measure the mastery of every specific objective. It tells the teacher and the learner how well a task can be done. The results of a good criterion-referenced test should thus tell a teacher exactly what a learner can or cannot do; at least under certain conditions.

Assessment in the new system focuses on the learner's ability to perform a certain task against a fixed criterion which is a nationally agreed upon standard. The learner should know that his or her performance will be composed against the agreed upon standard only and not against the other learners in the class. The shift from a norm-referenced approach to a formative, criterion-referenced approach means that the focus will move from comparison to the assessment of an individual's performance against predetermined criteria, that is, outcomes, or standards on the NQF. There is a shift from content measurement to performance assessment.

(Department of Education and Science and the Welsh Office, 1998:7).

#### **2.7.3.5 Continuous Assessment in Blended Teaching and Learning**

Since blended approach to teaching and learning build up from traditional approach, OBE and NCS, therefore continuous assessment (CAS) is part of it. Blended teaching and learning is mixture of different teaching, learning and assessment modalities. Formative and summative assessments are equally important in blended approach. Figure 2.10 below shows the blended teaching model used in this study.



**Figure 2.10** Blended Teaching Model followed in this study

#### **2.7.3.6 Computer-mediated Learning**

Learning is optimum when it is assisted and personalised (Gell-Mann, 1996).

Alonso, et al (2005:218) posit that in the olden days, the wealthy engaged tutors for their children, who thus received efficient personalised education. Computers are therefore, the potential saviours of the education system, because they can be used to personalise learning. They can design our learning according to our own knowledge and needs, record the progress we make, and tell us if any thought process is wrong so it can be corrected (Alonso, et al, 2005:218).

Gravett and Geyser (2004:158) posit that

Early attempts at using *WWW* as an educational application were most often referred to as web-based education (WBE), web-based instruction (WBI), or web-based learning (WBL). In some cases, the term “online education” or “online learning” were adopted. Today the phenomenon is often referred to as electronic learning or simply e-learning.

They further describe WBL as

Learning that is facilitated by using web-based technologies. As such, WBL is networked learning, connecting the constituents of the teaching-learning process into a dynamic husk. These constituents are typically regarded as the learner; the teacher or facilitator of learning; the knowledge objects or content; the envisaged outcomes in terms of knowledge, skills and attitudes; learner activities, and the medium of facilitation (Gravett & Geyser, 2004:158).

Furthermore, Gravett and Geyser (2004:158) maintain that the WBL is potentially the most powerful medium by which learning can be facilitated in the networked electronic environment. The delivery of computerised instruction can be facilitated either by using the Internet (or Intranet), or compact discs (CD-ROM or DVD), or hybrid deliveries, in which both the internet and CD technologies are used.

With the development of the internet, internet-based computerised learning, known as e-learning, has attracted the attention of educators. The European Commission (EC) (2001, as cited by Alonso, et al, 2005:218) defines e-learning as “the use of new multimedia technologies and the internet to improve the quality of learning by facilitating access to resources and services, as well as remote exchange and collaboration”, or “the use of network technologies to create, foster, deliver, and facilitate learning, anytime and anywhere”. Essentially, e-learning is an alternative way to teach and learn. It is a recent phenomenon that has not yet incorporated the pedagogical principles of teaching (Bixler & Spotts, 2000, in Alonso,et al, 2005:218). Recent research on e-learning tools for learning via the internet has found that the software design of these tools does not stretch to pedagogy, and the pedagogical manner in which these tools are used in teaching is left to the educators (Govindasamy, 2002).

#### **2.7.3.7 WBL Learning Environment**

The WBL environment is that electronic space where learning is facilitated. This environment is sometimes described as “virtual classroom” or “electronic classroom”. However, there is a problem with these descriptions, in that they could easily lead to the alternative conception that the WBL environment should imitate the conventional, face-to-face setting, and that the same kinds of resources, interactions, teaching and learning activities, and assessment practices are found “virtually” (Gravett & Geyser, 2004;159).

The WBL environment can be used to supplement conventional classroom instruction. Such courses are taught face-to-face, but may be supplemented by additional materials and activities that are made available on the web. Technology thus acts as an adjunct to the traditional classroom (Lant, 2002; as cited by Gravett & Geyser, 2004:159). In addition, Gravett and Geyser (2004:159) further state that the WBL can also be used as a substitute for classroom-based teaching. Such courses are considered to be ‘web-based’ or

'fully on-line' and all the constituents of the teaching and learning process are found within the WBL environment.

#### **2.7.3.8 The Role of WBL Learning Facilitator**

Gravett and Geyser (2004:168) state that "one of the most fundamental changes that WBL has brought about relates to the role of the learning facilitator." Gravett and Geyser (2004:168) further opines "conventionally, teaching was considered as a top-down activity, wherein learners were the recipients of information imparted by the instructor." Furthermore, Gravett and Geyser (2004:168) aver that "in the WBL environment, the instructor becomes a facilitator of learning, and his or her role may alternate between that of mentor, organiser, sage, knowledge broker, moderator and also fellow learner." The role of the teacher changes in terms of the form and level of support given to students. According to Relan and Gillan (1997) the teacher dethrones himself or herself as a disseminator of information, and instead becomes a facilitator for finding, assessing, and making meaning from information discovered in a variety of media. Reeves and Reeves (1997) describe the changing role of the teacher in this regard as a movement away from the traditional didactic role of the teacher as a "sage on the stage" to a facilitative role as a "guide on the side". The learning facilitator in this type of environment can adopt a number of facilitative roles and these should be entrenched into the instructional environment.

In this regard, the terms "coaching", "scaffolding" and "moderating" become relevant. Coaching describes an activity where the teacher provides information and assistance on demand (Oliver, 1998). In this case, the level of interaction is determined by the learners themselves as they engage with the teacher when needed, and also determining the scope and extent of coaching.

Oliver (1998:96) states that "scaffolding is used as supportive structures by learning facilitators within the WBL environments, and enables students to perform tasks and activities which may normally be beyond their means." In this

regard, “scaffolding acts as a communication process where presentations and demonstration by the learning facilitator are contextualised for the learner, the performance of the learner is coached and articulation is elicited” (Gravett & Geyser, 2004:169). As the learner achieves expertise and proficiency, the scaffold is removed to the point where the student can stand alone. This process is called fading. The new scaffolding is generated for the next learning activity (Gravett & Geyser, 2004:169).

As online moderator, three functions of the learning facilitator can be identified: contextualising functions, monitoring functions, and meta-functions (Freenberg, 1989). Gravett and Geyser (2004:159) indicate that

Because of the absence of the physical cues that are found in the traditional classroom, the instructor must compensate by continually contextualising and monitoring. This means students must be explicitly told what to do in any given situation.

#### **2.7.3.9 Constructivism in the Electronic Learning Environment**

Constructivists believe that knowledge is constructed by learners as a result of their interactions with the natural world in a socio-cultural context, and that it is mediated by their prior knowledge (Gravett & Geyser, 2004:170). The learner’s prior knowledge structure acts as both a filter and facilitator of new ideas and experiences. This knowledge structure may become transformed and expanded during learning. In order to facilitate constructivist learning in WBL environments, the activities must be:

- *Active*: they must engage learners in mindful processing of information where they are responsible for the result.
- *Constructive*: they must facilitate knowledge construction. Learners integrate new ideas with prior knowledge in order to make sense or make meaning or to reconcile a discrepancy, curiosity or puzzlement. They construct their own meaning from different phenomena.

- *Collaborative*: learners naturally work in learning and knowledge –building communities, exploring each others skills, while providing social support and observing the contributions of each member.
- *Complex*: learning situation need to engage students in solving complex and ill-structured problems, as well as simple problems. Unless learners are required to engage in higher order thinking, they will develop oversimplified views of the world.
- *Contextualised*: students access background and contextual materials of various sorts to aid interpretation and argumentation. When learners are provided with real contextual materials, they are able to practise and transfer ideas to other contextual situations.
- *Reflexive*: when learners articulate what they learn, they reflect on the processes, understand more, and are entitled to use knowledge that they have constructed in a new situation.
- *Authentic*: learners must see the relevance of the knowledge and skills to their lives, and apply them to their problems.
- *Facilitative of multiple perspectives*: learners learn in a variety of ways. The more opportunities they have, and the more actively engaged they are, the richer their understanding (Gravett & Geyser, 2004:171 – 172).

#### **2.7.3.10 Implementation of a Blended Approach**

Alonso *et al* (2005:231) opine that education specialists advocate a blended learning solution (Cross, 2003; Davis, 2003; Hulm, 2003; Thorne, 2003). According to Alonso *et al* (2005:231) blended learning is used to describe learning that mixes various event-based activities: self-paced learning, live e-learning and face-to-face classrooms. Alonso *et al* (2005:231) further describe these event-based activities as follows:

- *Self-paced learning* is what the learner does by executing the e-learning process, self-paced activities can be taken at the learner's leisure, that is, can be taken anytime and anywhere... The value of self-paced learning is

not only that it can reach everyone at any time and anywhere, but that it can teach the learner appropriately, providing the right skills at the right time.

- *Live e-learning* takes place in a virtual classroom at a scheduled time at which learner undertakes to attend, just as they would a traditional class, minus travel. Learners can collaborate, share information, and ask questions of one another and of the instructor in real time. Live e-learning is good for sharing information. This type of training works best if the class size is limited to 25 people to allow for group interaction.
- *Traditional classroom training* will always be despite its defects, an effective means of learning. Classroom training is still unbeatable for the amount of face-to-face interaction with both the instructor and classmates that is necessary to learn certain management, leadership, and other highly collaborative skills.

Blended learning embodies the interrelated characteristics advocated by Donovan, Bransford, Pellegrino (1999, as cited by Alonso, *et al*, 2005:233):

- Maintenance of a learning-centred environment;
- Provision of knowledge-centred environment;
- Formative assessment that makes student thinking visible to instructors and colleagues; and
- Building of an interactive learning community.

Blended learning therefore combines training, coaching, and self help. Davies (2003, as cited by Alonso *et al*, 2005:233) posits that blended learning involves more management, accepting that people development is a continual process, through which experience doing the work is gained.



Table 2.3 below shows a glimpse of student learning styles as given by Imenda (2010:3):

**Table 2.3** A Glimpse of Student Learning Styles

<b>A GLIMPSE OF STUDENT LEARNING STYLES</b>		
<b>Learning Style</b>	<b>Student Characteristic</b>	<b>Teaching Strategy</b>
Active	Likes being busy – “doing”	Discussion and Problem-solving: good for retention.
Reflective	Likes to work alone; Needs time to digest.	Ask students to summarise and apply.
Sensory	Memorizing “facts” and hands-on work.	Give many examples; practical work.
Intuitive	Like experimenting.	Discovery; Experimenting
Visual	Learns best from seeing.	Use pictures, diagrams, charts, videos, demos, etc.
Verbal	Learns best from words.	Present and summarise verbally.
Sequential	Logical steps; linear.	Break material into smaller logical chunks; give overview.
Global	Digests material in leaps and bounds; bigger picture.	Give overview; show relationship with past and future.

Table 2.3 gives a picture of what a class may consist of in terms of learner characteristics. Knowing student characteristics and their learning styles helps an educator to vary his or her methods of teaching accordingly. It is clear from Table 2.3 that using one approach, for example, lecture, could do injustice to other learners in class.

### **2.7.3.11 Categories of Learner Experiences**

Categories of learner experiences are briefly discussed below under a couple of sub-headings.

#### ***Factual knowledge through direct instruction***

In science education like most other subjects and learning areas, there exists a body of knowledge (Dugger, 1997:126-127) that needs to be acquired before learners are in a position to apply this knowledge to problem solving activities.

The ability to apply basic conceptual knowledge gained through direct instruction requires self-confidence. In turn, self-confidence implies empowerment which is directly linked to self image (Coetsee, 1992:24).

### ***Basic manipulative skills through direct instruction***

Basic manipulative skill development forms an integral part of the realisation of design solutions and this can only be acquired through practice (Mawson, 2003). Manipulative skill development in physical science is linked to empowering learners through hands-on exploration in the context of science problem solving. Johnson (1997:167) asserts that “manipulative skills should be developed through the use of tools, equipment and materials in focused practical tasks and activities”.

### ***Co-operative learning as an approach in blended learning***

A number of researchers (Cavalier, Klein & Cavalier, 1995; Johnson & Johnson, 1989; King, 1984) have found that group interactive behaviour is related to improved performance when co-operative instructional approaches to learning are used. Through the exchange of ideas, “learners develop shared meanings that allow group members to communicate effectively with each other” (Wheatley, 1991:19). By interacting with others, “learners have the opportunity to learn from each other, share knowledge, and engage in competition, co-operation, collaboration, conversation and negotiation of meaning “(Johnson, 1997:171

One particularly important development in schools has been the greater use of small group work. Small group work refers to academic tasks and activities undertaken by a group of pupils, which involves some degree of discussion, reflection and collaboration. The optimum size for small group work for most

types of tasks is probably about five (Waterhouse, 1983) although other types of group work can be undertaken by groups as small as two.

Whitaker (1984) lists the value of small group work as follows:

- It creates a climate in which pupils can work with a sense of security and self-confidence;
- It facilitates the growth of understanding by offering the optimum opportunity for pupils to talk reflectively with each other; and
- It promotes a spirit of co-operation and mutual respect.

### ***Discovery learning as an approach to learning in blended learning***

This approach involves the discovery by the learner of what he/she is capable of thinking and/or doing for himself/herself (Bruner, 1996:106). In order to achieve discovery, the learner must incorporate and integrate information with what is already known as new relationships are formed (Biehler & Snowman, 1993:425). According to Mwamwenda (1995:213), “discovery does not necessarily mean coming up with knowledge that is unknown to someone else but coming up with knowledge by oneself”. An important component of discovery in learning is the discovery of relationships between parameters (Biehler & Snowman, 1993: 427). In essence, discovery learning involves rearranging or transforming information so as to obtain new insights. Given the problem solving nature of science education, the discovery approach to learning is a valid form of knowledge construction, whereby learners take responsibility for their own learning. Roth (1990:155) asserts that “learners have opportunities to explore their own ways of thinking about the phenomena under discussion”.

### ***Enquiry-based learning as an approach to learning in blended learning***

Enquiry-based learning is whereby the learner questions, investigates and seeks out information, thereby assuming responsibility for his/her own learning, with the teacher playing a facilitator role. According to Eggen and Kauchak (1996:236), “involving learners in inquiry learning is one of the effective ways to help them develop their higher-order and critical thinking skills”, leading to empowerment. Schwaller (1995:438) maintains that “enquiry learning is an investigative learning process which is often equated to experimentation, discovery and problem solving”. Duke (1990:57) claims that “it is more important that learners become familiar with the enquiry process than to obtain the correct answers”. It is the view of Orlich, Harder, Callahan, Kauchak and Gibson (1994:271) that “the enquiry process must be learnt, demonstrated and assimilated into learning styles”.

According to Anderson (2002:1), teachers considering new approaches to education face many barriers and dilemmas, many of which have origins in their beliefs and values which are connected to constructivism. He lists them as follows:

- Limited ability to teach constructively due to inadequate in-service education which is not sustained for a sufficient number of years;
- Prior commitments to textbooks and coverage of content because of a perceived need to prepare students for the next level of schooling;
- The challenges of new teacher and student roles;
- The challenge of assessment;
- Difficulties of group work;
- Parental resistance; and
- Lack of resources.

Coetzee (2008:88) asserts that Anderson’s list is compatible with the issues educators have experienced in South Africa with the OBE implementation.

### ***Experiential learning as an approach to learning in blended learning***

Experiential learning is considered to be a powerful and empowering tool to making science education more meaningful and relevant to the lives of learners (Reddy, *et al.*, 2005:29). According to Johnson (1997:47),

Current approaches that emphasize experiential learning include among other things, discovery learning, inquiry learning, activity based learning, project based learning, action learning and hands-on experience.

Johnson further states that each of these approaches emphasizes the importance of learning from experience, that is goal-driven, activity based and problem centred. Down (1996:233) points out that “one reason why learner centredness stresses problem solving as opposed to direct instruction is that learning from experience is a more active and valid form of learning”. Henak (1992:14) stresses that “meaning is added when learners are actively involved in learning experiences”. Meaning, according to Henak, can come from activities that are relevant to real life problems. However, it does not mean that if there are no activities done by learners, there is no meaningful learning. Learning can be meaningful even if the learner is listening to a lecture by the educator. Listening skill is one of the skills that should be developed in the learners. It can be concluded therefore that whatever instructional strategies are employed by educators, they should lead to meaningful learning.

It is important to make a clear distinction between receptive and discovery learning, and between rote and meaningful learning so that there is no confusion as to how learners learn. Ausubel makes a distinction between rote and meaningful learning, which is important for teaching higher order thinking (Ivie, 1998). Ivie (1998) states that rote learning occurs when the learner memorizes information in an arbitrary fashion. The knowledge or information is stored in an isolated compartment and is not integrated into the person’s larger cognitive

structure (Ivie, 1998). According to Ausubel (1962:215-216), “rotely learned materials are discrete and isolated entities which have not been related to established concepts in the learner’s cognitive structure”. Rote learning is easily forgotten because it is not anchored to existing concepts. According to Ausubel (1978), rote learning does not involve subsumption (i.e., related to meaningful materials).

On the other hand, Ivie (1998) states that meaningful learning is part and parcel of higher order thinking. Such thinking takes place when the interrelationship between two or more ideas, old and new, is grasped. In this regard, Ausubel and Robinson (1969:46) contend as follows:

A first prerequisite for meaningful learning is that the material presented to the learner be capable of being related in some ‘sensible’ fashion. Second, the learner must possess relevant ideas to which the new ideas can be related or anchored. Finally, the learner must actually attempt to relate, in some sensible way, the new ideas to those which he presently possesses.

According to Ausubel (1978), in meaningful learning, the learner must discover information through problem solving, implying that if any of the three above-mentioned conditions is missing learning is not meaningful but rote. For this reason, Ausubel (1968) contends that, the most important single factor influencing learning is what the learner already knows. Indeed, teachers have always recognized the need to start instruction from ‘where the student is’.

Ausubel also gives further clarity on reception, discovery, meaningful and rote learning: Verbal reception learning is not necessarily antithetical to higher order thinking, though the method has been characterized as “parrot-like recitation and rote memorization of isolated facts” (Ausubel, 1963:15). Reception learning is not invariably rote; likewise, discovery learning is not always meaningful. Either reception learning or discovery learning can lead to rote or meaningful learning

(Ivie, 1998). In this regard, Ausubel (1961: 17) states that “the learning outcomes must necessarily be rote and meaningless” if the learner merely memorizes the material (even if the conclusions have been arrived at by the discovery method) (Ivie, 1998). It’s for this reason that Reception or Discovery learning may promote either rote or meaningful consequences. One does not inherently infer the other. Ivie (1998) further maintains that the whole question of rote learning versus meaningful learning depends upon whether or not the new information is integrated into the learner’s cognitive structure in an enduring and meaningful way.

#### **2.7.3.12 Importance of Blended Teaching**

Based on the above views on learning, there must be therefore a continuum in the methods of teaching used by educators, that is, in one lesson the lecture method can be followed by a demonstration, then question and answer method, and so on. Methods of teaching are not discrete but interrelated. One method is used in conjunction with another. For example, while an educator is doing a demonstration to clarify a concept, at the same time there are a lot of explanations (lecture method), questions being asked and learners giving answers (question and answer method). In the same lesson the educator may allow learners to practise the same skills after a demonstration (hands-on exploration). Therefore, no method of teaching is an island.

#### **2.7.3.13 Blended Learning Models**

Valiathan (2002) categorizes blended learning into three models:

- Skill-driven learning, which combines self-paced learning with instructor or facilitator support to develop specific knowledge and skills;
- Attitude-driven learning, which mixes various events and delivery media to develop specific behaviours;

- Competency-driven learning, which blends performance tools with knowledge management resources and mentoring to develop workplace competencies.

Table 2.4 shows the key features and the approaches adopted by each model as given by Valiathan (2002).

**Table 2.4** Key Features of the Blended Learning Models

	WHY	HOW
<b>Skill-Driven Model</b>	Learning specific knowledge and skills requires regular feedback and support from the trainer, facilitator, or peer.	<ul style="list-style-type: none"> <li>• Create a group-learning plan that's self-paced but bound to a strict schedule.</li> <li>• Pad self-paced learning material with instructor-led overview and closing sessions.</li> <li>• Demonstrate procedures and processes through synchronous online learning labs or traditional classroom setting.</li> <li>• Provide email support.</li> <li>• Design long-term projects.</li> </ul>
<b>Attitude-Driven Model</b>	Content that deals with developing new attitudes and behaviours requires peer-to-peer interaction and a risk-free environment.	<ul style="list-style-type: none"> <li>• Holds synchronous Web-based meetings (Webinars).</li> <li>• Assign group projects (to be completed offline).</li> <li>• Conduct role-playing simulations.</li> </ul>
<b>Competency-Driven Model</b>	To capture and transfer tacit knowledge, learners must interact with and observe experts on the job.	<ul style="list-style-type: none"> <li>• Assign mentors.</li> <li>• Develop knowledge (LCMS/LMS).</li> </ul>

Valiathan (2002) further describe the three models as follows:

- *Skill-driven model*: Blended learning that is skill-driven mixes interaction with a facilitator through email, discussion forums, and face-to-face meetings with self-paced learning, such as Web-based courses and books. This type of approach is analogous to a chemical reaction, in which interaction with the instructor or facilitator acts as a catalyst to achieve the desired reaction – learning. The trainer should monitor progress and contact the learner, evaluate online project work, build and



facilitate an online community for the course participants, and be available via email or threaded discussion to respond to content questions.

Indeed, this approach works best when people are learning content at the knowledge or application levels. Techniques to incorporate skill-driven blended learning include:

- Creating a tightly scheduled group learning plan;
  - Using instructor-led overview and closing sessions;
  - Using synchronous learning labs; and
  - Providing support to learners through email.
- *Attitude-driven model:* This approach blends traditional classroom-based learning with online collaborative learning events. At times, the nature of the content, as well as the desired outcome (developing attitude and behaviour) necessitates the inclusion of collaborative learning that's facilitated through face-to-face sessions or technology-enabled collaborative events. Developers should use this approach to teach content that requires learners to try out new behaviours in a risk-free environment.
  - *Competency-driven model:* learning that facilitates the transfer of tacit knowledge requires a competency-driven approach. Because people absorb tacit knowledge by observing and interacting with expert on the job, activities may include a blend of online performance support tools with live mentoring.

## **2.8 CONCLUSION**

In this chapter, a number of conceptual and theoretical perspectives have been reviewed, with regard to conceptual difficulties and alternative conceptions in mechanics, generally, and also more specifically in relation to grade 12 physical science curriculum. The following were the main themes that were discussed:

conceptual difficulties in mechanics; alternative conceptions in mechanics; learning theories; activity theory; curriculum development and implementation; traditional, OBE and the blended approaches to teaching and learning. The conceptual models underlying each intervention (traditional, OBE and blended) formed part of this chapter. The next chapter deals with research methodology.

## **CHAPTER THREE**

### **RESEARCH METHODS**

#### **3.1 INTRODUCTION**

This chapter follows on chapter two which dealt with the theoretical framework and review of literature. Some theoretical ideas about conceptual difficulties and alternative conceptions in mechanics; learning theories; curriculum development; traditional, OBE and blended approaches were discussed. Accordingly, the theoretical framework and the review of literature laid the foundation for exploring the problem further through the use of data collection instruments described in this chapter. Questionnaires, pre-tests, three interventions and post-tests were all used in order to provide the necessary answers to the research questions of this study. This chapter focuses on the research design, the description of the population and sample, instrumentation, as well as methods used in data collection.

#### **3.2 THE RESEARCH QUESTIONS RE-STATED**

This study sought to find answers to the following research questions:

- 3.2.1 What are the conceptual difficulties experienced by grade 12 physical science learners in mechanics?
- 3.2.2 What are the most prevalent alternative conceptions relating to mechanics amongst grade 12 physical science learners?
- 3.2.3 Which intervention(s) among the traditional, OBE-based and blended can best alleviate the conceptual difficulties and alternative conceptions relating to mechanics for grade 12 physical science learners?

### **3.3 STATISTICAL HYPOTHESES RE-STATED**

Research questions 3.2.1 and 3.2.2 were addressed through review of literature, paper-pencil testing and content analyses. However, in order to address Research Question 3.2.3 a number of statistical hypotheses were generated for statistical testing. In each case, the 95% level of significance (that is,  $\alpha = 0,05$ ), and the relevant degrees of freedom were used in determining whether or not statistical significance had been met. The hypotheses were stated as follows:

- 3.3.1 An intervention based on the traditional instructional approach has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- 3.3.2 An OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- 3.3.3 A Blended instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions in mechanics.
- 3.3.4 There is no statistically significant difference amongst OBE-based, traditional and blended instructional interventions in alleviating the conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.

### **3.4 RESEARCH DESIGN**

In attempting to alleviate the conceptual difficulties and alternative conception held by grade 12 physical science learners in mechanics, an instructional programme was designed and implemented in three high schools drawn from Empangeni Education District. Experimental design was the main design chosen for this study. Specifically, a quasi-experimental design, known as non-

equivalent comparison-group design, as described by Imenda and Muyangwa (2006), was considered the most appropriate research design for an investigation of this nature. According to Imenda and Muyangwa (2006:37-38):

The experiment is the ultimate form of research design, providing the most rigorous test of hypotheses that is available to the natural scientist. In the field of education a sizeable number of research projects deals with testing the effects of new educational materials and practices on student learning. Thus, the results of educational experiments may have a direct impact on the adoption of new curriculum materials and instructional modes in schools.

Imenda and Muyangwa (2006:38) further posit that “most of the basic experimental designs used in the social sciences are an adoption of those obtaining in the physical and biological sciences.” This type of research design is befitting here since this is a science education study, specifically dealing with mechanics which is the branch of physics. Furthermore, Imenda and Muyangwa (2006:38) maintain that

The typical experimental design involves the selection of a sample of subjects; random assignment of these subjects to experimental and comparison groups; the exposure of the experimental group to a treatment that is withheld from the control/comparison group; the evaluation of the two groups on the dependent or responding variable (that is, the variable that you are attempting to change as a result of the treatment or intervention); discussion of findings; formulation of conclusions and recommendations.

The non-equivalent comparison-group design is probably the most widely used quasi-experimental design in educational research (Imenda & Muyangwa, 2006). By way of definition, quasi means ‘seemingly’, ‘being partly or almost’, it is a Latin word for ‘as if, almost’ (South African Concise Oxford Dictionary, 2005:956). Neuman (2000) classifies quasi-experimental design under the quantitative

research design category. Kumar (2005:86) posits that quasi or semi-experimental design has the properties of both experimental and non-experimental studies; part of the study may be non-experimental and the other part experimental. Thus, with regard to comparative study, Kumar (2005:106) opines as follows:

With a comparative design, as with most other designs, a study can be carried out either as an experiment or as a non-experiment. In the comparative experimental design, the study population is divided into the same number of groups as the number of treatments to be tested. For each group the baseline with respect to the dependent variable is established. The different treatment models are then introduced to the different groups. After a certain period, when it is assumed that the treatment models have had their effect, the 'after' observation is carried out to ascertain any change in the dependent variable. The degree of change in the dependent variable in the different population groups is then compared to establish the relative effectiveness of the various interventions.

One important characteristic of experimental designs is that they make use of control or comparison groups which do not receive the "treatment" or "intervention" which the other group(s) receives. In particular, where there is only one treatment group, it is important to have a control or comparison group against which the variance in the performance of the treatment group can be compared, to ensure that such variance is not due to natural factors like maturation.

A notational system in which X stands for an intervention, treatment or independent variable, O stands for an observation or test and subscripts 1 through  $n$  refer to the sequential order of implementing treatments or intervention ( $X_1 \dots X_n$ ) or of recording observation, such as test ( $O_1 \dots O_n$ ) (Cook & Campbell, 1979).

In this study, the quasi-experimental non-equivalent comparison-group research design was followed to investigate the extent to which the traditional, OBE and the blended approaches could help alleviate or overcome the conceptual difficulties and alternative conceptions held by high school learners in mechanics (Imenda & Muyangwa, 2006). This design may be represented as follows:

OBE group	:	O <sub>1</sub>	X <sub>1</sub>	O <sub>2</sub>
		-----		
Traditional group	:	O <sub>1</sub>	X <sub>2</sub>	O <sub>2</sub>
		-----		
Blended group	:	O <sub>1</sub>	X <sub>3</sub>	O <sub>2</sub>
		-----		
Comparison group	:	O <sub>1</sub>		O <sub>2</sub>

Key: O<sub>1</sub> = pre-test  
 O<sub>2</sub> = post-test  
 X<sub>1</sub> = intervention for the traditional group  
 X<sub>2</sub> = intervention for the OBE group  
 X<sub>3</sub> = intervention for the blended group

De Vos, Strydom, Fouche and Delport (2005:139) describe the broken line among groups as a line that serves to emphasise that the groups were not obtained by random assignment. De Vos *et al* (2005) further state that the comparison group receives both the pretest O<sub>1</sub> and the posttest at the same time as the experimental groups, but it does not receive the treatment. The experimental group is exposed to the independent variable (treatment or intervention) X, whereas the comparison group is not exposed to X.

By way of definition, an independent variable is a variable that is responsible for bringing about change and a dependent variable is a variable that changes due

to variations in the independent variable (de Vos, *et al*, 2005). In this study, independent variables were treatments or interventions (traditional, OBE and blended interventions) and dependent variables were the conceptual difficulties and alternative conceptions held by grade 12 physical science learners in mechanics.

Kumar (2005), states that all other factors that affect the relationship between the dependent and the independent variable are called extraneous variables. In the same way chance variables are changes in the dependent variable because of the respondent's state of mood or ambiguity in the research instrument; the error thus introduced is called chance or random error.

Hence, in any causal relationship, changes in the dependent variable may be attributed to three types of variables (Kumar, 2005:86):

$$\begin{array}{|c|} \hline \text{Change in} \\ \text{the} \\ \text{dependent} \\ \text{variable} \\ \hline \end{array} = \begin{array}{|c|} \hline \text{Change} \\ \text{because of} \\ \text{the} \\ \text{independent} \\ \text{variable} \\ \hline \end{array} \pm \begin{array}{|c|} \hline \text{Change} \\ \text{because of} \\ \text{the} \\ \text{extraneous} \\ \text{variable} \\ \hline \end{array} \pm \begin{array}{|c|} \hline \text{Change} \\ \text{because of} \\ \text{chance} \\ \hline \end{array}$$

In this study, learners were afforded an opportunity to freely express themselves regarding their understanding of basic mechanics concepts and principles. The researcher then identified conceptual difficulties and alternative conceptions in mechanics through learners' questions, comments, responses to tests and work at the chalk board. Models of their knowledge construction and conceptual development were also built. There were interactions among learners and these interactions occurred openly while models were being developed. Three interventions then followed.



The researcher sought to compare the effectiveness of different treatment (interventions) modalities, that is, traditional, OBE and blended approaches. Kumar (2005:106) avers that “in such situations a comparative design is appropriate”. In this regard, the study therefore involved four (4) high schools drawn from Empangeni Education District. The four (4) were regarded as four (4) groups from which the quasi-experimental non-equivalent comparison-group research design was implemented. There were thirty five (35) grade 12 physical science learners selected from each school. The researcher organized special classes from these schools since, as a researcher, he was not allowed to disturb the normal classes of the schools. Imenda and Muyangwa (2006:106) suggest that in causal-comparative and experimental research, it is desirable to have a minimum of 15 cases in each group to be compared. Random assignment of subjects to treatment and comparison groups was not possible and hence the quasi-experimental design was chosen for this study. Thus, the formation of groups was not done through randomization of subjects to the respective experimental groups and as well as to the comparison group.

One of the four (4) groups was used as a comparison group. All the four (4) groups were pre-tested on the dependent variables, that is, conceptual difficulties and alternative conceptions. The pre-test used in this design was aimed at detecting any incidence of initial differences among the four (4) groups. Thus the teaching and learning approaches, that is, traditional, OBE, and blended approaches, served as independent variables. These teaching and learning approaches were assumed to bring about the change in learners’ conceptual development with regard to conceptual difficulties and alternative conceptions that they held in mechanics. The treatments or interventions were then administered to the remaining three (3) groups. In the same way, all the four (4) groups were post-tested on the dependent variables.

The summary of the steps of the design was as follows:

- (i) The learners completed a **questionnaire** to indicate their personal information (age, sex, repeater, schools attended, first and second language) and their preference of instructional and evaluation methods. (See Appendix A).
- (ii) The learners wrote a multiple choice **pre-test** to determine possible alternative conceptions on mechanics (that is, force, Newton's laws, projectile motion, work and energy) (See Appendix B).
- (iii) **Interventions:** for the traditional group the concepts were treated according to the traditional way of teaching, which involved lecturing and sole use of the prescribed textbook as reference. For the OBE (constructive) group the concepts were treated according to the OBE approach, which was mainly learner-centred. For the blended group the concepts were treated with different approaches (including computer mediated teaching).
- (iv) The students wrote a multiple choice **post-test**, equivalent to the pre-test, on projectile motion, Newton's laws, work and energy, to determine the effectiveness of the three interventions (traditional, OBE, and blended). (See Appendix C).
- (v) The researcher made an arrangement with the physical science educator to do a different section or knowledge area with the comparison group other than mechanics during intervention period. Hence, the **comparison group** studied **chemistry** topics during the intervention period.

The differences in the post-test scores among the four (4) groups (if any) were meant to indicate the effectiveness of the respective interventions. The degree of change in the dependent variables for the different groups was then compared to establish the relative effectiveness of the three interventions (traditional, OBE and blended approaches). The changes in the average level of comprehension for the four (4) groups were also compared to establish which teaching model/approach was the most effective.

This study also used the concept of “normalised gain scores” (Hake, 1997).

By way of definition, the normalised gain ‘g’ for a treatment is defined as  $g = \text{Gain} / [\text{Gain maximum possible}]$  (Hovland, Lumsdaine & Sheffield, 1949; Gery, 1972; Hake, 1998). Thus, if the class average score is 40% on a pre-test and 60% on the post-test then the class average normalised gain  $\langle g \rangle = (60\% - 40\%) / (100\% - 40\%) = 20\% / 60\% = 0,33$  (Hake 1998a; Meltzer, 2002b). Hake (1997:65) further defines “the average normalised gain  $\langle g \rangle$  for a course as the ratio of the actual average gain  $\langle G \rangle$  to the maximum possible average gain.” Mathematically, Hake (1997:65) defines the average normalised gain as “ $\langle g \rangle \equiv \% (G) / \% (G)_{\max} = \% (S_f) - \% (S_i) / 100 - \% (S_i)$ , where  $(S_f)$  and  $(S_i)$  are the final (post) and initial (pre) class averages.”

Furthermore, Hake (1997) defines and gives the meaning of “the average normalised gain” as follows: High average normalised gain scores are those with  $\langle g \rangle \geq 0,7$ ; medium average normalised gain scores are those with  $0,7 > \langle g \rangle \geq 0,3$  and low average normalised gain scores are those with  $\langle g \rangle < 0,3$ . Low average normalised gain is a characteristic of traditional approaches to teaching and learning.

Research shows that  $\langle g \rangle$  is a much better indicator of the extent to which a treatment or intervention is effective than either gain or post-test scores on their own. For example, if the treatment yields  $\langle g \rangle > 0,3$  for the mechanics intervention, then the intervention could be considered as falling within the

'interactive-engagement zone' (Hake, 1998a; Meltzer, 2002b). By way of definition, Hake (1997:65) defines

interactive engagement methods as those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors.

In the same way, Hake (1997) also defines traditional approaches to teaching and learning as those that make little or no use of interactive engagement methods, relying primarily on passive-student lectures, recipe labs, and algorithmic-problem examinations. However, the normalised gain score  $\langle g \rangle$  does not provide a definitive assessment of the overall effectiveness of, say, an introductory physics intervention in mechanics, the normalised gain score would assess "only the attainment of a minimal conceptual understanding of mechanics" (Hake, 2002e:3). Furthermore, Hake (1998b) indicates that among desirable outcomes of the introductory physics intervention that  $\langle g \rangle$  would not measure directly would include things like students':

- Satisfaction with and interest in physics;
- Understanding of the nature, methods, and limitations of science;
- Understanding of the processes of scientific inquiry such as experimental design, control of variables, dimensional analysis, order-of-magnitude estimation, thought experiments, hypothetical reasoning, graphing and error analysis;
- Ability to articulate their knowledge and learning process;
- Ability to collaborate and work in groups;
- Communication skills;
- Ability to solve real-world problems;
- Understanding of the history of science and the relationship of science to society and other disciplines; etc.

In this regard, to determine the effectiveness of the respective interventions (traditional, OBE and blended) normalised gain scores were computed. The

inclusion of the normalised gain score concept in this study was essential since the study is concerned with the alleviation of conceptual difficulties and alternative conceptions in mechanics.

### **3.5 TARGET AND ACCESSIBLE POPULATION**

This study focused on grade 12 learners' conceptual difficulties and alternative conceptions in mechanics. Empangeni Education District grade 12 physical science learners constituted the target population of this study. Therefore, all grade 12 physical science learners in Empangeni Education District formed a natural grouping in respect of this research topic. By way of definition, Imenda and Muyangwa (2006:97) define a target population as the group of subjects to whom the findings of a given study will be generalized. It is the target population that enables the researcher to collect the information required to answer or address the research questions, objectives or hypotheses.

There are four (4) education circuits in the Empangeni Education District, that is, Lower Umfolozi, Mthunzini, Nkandla and Eshowe. For the purpose of this study, all grade 12 physical science learners in the Lower Umfolozi Education Circuit constituted the accessible population for the researcher, since Empangeni Education District is too wide. Lower Umfolozi Education Circuit was a sub-population of the target population, that is, Empangeni Education District. The accessible population was deemed to be identical to the target population in that all types/categories of schools that are found in the target population are also found in the accessible population. The accessible population was chosen because it was near enough to the researcher and possessed the same major and critical characteristics of the target population.

### **3.6 THE RESEARCH SAMPLE AND SAMPLING PROCEDURES**

The research sample for this study consisted of 140 grade 12 physical science learners drawn from four (4) high schools from Empangeni Education District, specifically the Lower Umfolozi Education Circuit as the accessible population. These high schools were coded as A, B, C and D. There were 35 grade 12 physical science learners selected per school. Thus, a research sample is a small group, selected from the population to provide subjects (Schumacher & McMillan, 1993:16).

Sampling is the process of selecting a number of individuals for a study in such a way that the individuals represent the larger group from which they were selected. However, one of the reasons for sampling is to reduce expenses. Non-probability sampling specifically known as convenience sampling was used to select participating schools. According to Leedy and Ormrod (2005:206), convenience sampling “takes people or other units that are readily available” for selection. Leedy and Ormrod (2005:206) further state that “in this type of sampling some members of the population have little or no chance of being sampled”.

There were fifteen (15) high schools with computer facilities in the Lower Umfolozi Circuit. These schools were selected according to the number of intervention groups including the comparison group. Three schools were selected for the three interventions and one for comparisons purposes. In total, four (4) high schools participated in the study. These schools were geographically convenient to reach for the researcher.

In this regard, not all high schools in the Lower Umfolozi Education Circuit were sampled but only those high schools that were having computer facilities because of the nature of the study.

### 3.7 MIXED METHODS RESEARCH AND TRIANGULATION

This study used a quasi-experimental design and hence, it falls under quantitative research paradigm, although some aspects of qualitative data collection and analysis. The study had four hypotheses to be tested which also made the study quantitative in nature. In the quantitative paradigm: (1) the emphasis is on facts and causes of behaviour; (2) the information is in the form of numbers that can be quantified and summarised; (3) the mathematical process is the norm for analysing numerical data; and (4) the final result is expressed in statistical terminologies (Golafshani, 2003; Bogdan & Biklen, 1998; Charles, 1995). The four statistical hypotheses of this study related to the third research question which made use of the analysis of variance (ANOVA) to determine the most effective teaching approach among the traditional, OBE and the blended approaches. Thus, it could be said that this study used mixed methods research by combining both quantitative and qualitative methods. According to Johnson, Onwuegbuzie and Turner (2007), different researchers define mixed methods research in different ways. It is however noted that all these definitions converge at one point by combining qualitative and quantitative research methods in data collection and/or data analysis techniques. There is, therefore a plethora of ways to define mixed methods research. Johnson, *et al*, (2007:123) generally define mixed methods research as

the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purpose of breadth and depth of understanding and corroboration.

According to Rossman and Wilson (1985) there are three reasons for combining quantitative and qualitative research:

- to enable corroboration of different approaches through triangulation;
- to enable, or to develop, analysis in order to provide richer data; and

- to initiate new modes of thinking by attending to paradoxes that emerge from the two data sources.

Denzin (1978) defines triangulation as the combination of methodologies in the study of the same phenomenon. Denzin (1978) further outlines the four types of triangulation as follows:

- Data triangulation (the use of a variety of sources in a study);
- Investigator triangulation (the use of several different researchers);
- Theory triangulation (the use of multiple perspectives and theories to interpret the results of a study); and
- Methodological triangulation (the use of multiple methods to study a research problem)

Furthermore, there are five purposes or rationales of mixed methodological studies as identified by Greene, Caracelli, and Graham (1989):

- Triangulation (seeking convergence and corroboration of results from different methods studying the same phenomenon);
- Complementarity (seeking elaboration, enhancement, illustration, clarification of the results from one method with the results from other method);
- Development (using the results from one method to help inform the other method);
- Initiation (discovering paradoxes and contradictions that lead to a reframing of the research question); and
- Expansion (seeking to expand the breadth and range of inquiry by using different methods for different inquiry components).

Reflecting the above definitions and purposes for mixed methods research, the researcher found good reason for using both quantitative and qualitative research methods.



To address the first and the second research questions, the researcher used qualitative research method as follows:

- Collection of biographical information of learners, and their preferences on teaching methods, especially their opinions and comments on OBE and blended teaching approaches to teaching and learning;
- Identification of the conceptual difficulties in mechanics with regard to “work and energy” through learners’ motivations, statements and comments;
- Identification of the alternative conceptions in mechanics with regard to “projectile motion, force and Newton’s Laws through learners’ motivations, statements and comments; and
- Finally, the researcher interpreted and categorised all motivations qualitatively in accordance with emerging themes.

The quantitative research approach was used for the following aspects of the research:

- Marking: marks were allocated for the intended response, for any self-rating and for any motivation;
- Analysis: analysis of the multiple choice answers which was then followed by statistical testing;
- Statistical hypotheses: the third research question required the statistical analysis of the learners’ test scores as the hypotheses were related to it (third research question); and
- Motivations: open-ended motivations were analysed both qualitatively and quantitatively.

Glolafshani (2003:597) avers that “quantitative research allows the researcher to familiarize him/herself with the problem or concept to be studied, and generate hypotheses to be tested”.

The information gathered through qualitative analysis of data was blended with the information gathered through quantitative data analysis to provide richer data.

### **3.8 THE RESEARCH INSTRUMENT**

This section describes the instrument developed to gather the required information relevant to the study. This is followed by the determination of the reliability and validity of the instrument. The following research instrument was used in this study:

#### **3.8.1 THE TEST IN BASIC MECHANICS (TBM)**

A researcher-designed test: the Test in Basic Mechanics (TBM) was used in this study to collect the information required to answer the three research questions – and was used as both pre- and posttest (Appendix A). The TBM comprised two sections, and was developed by the researcher to obtain biographical information and determine the familiarity of learners about mechanics (projectile motion, forces, Newton's laws, work and energy). The test comprised both structured and open-ended items. The structured items focused on biographical information, whereas the open-ended ones sought to elicit student's own view regarding mechanics. Thus, Section A was aimed at collecting information pertaining to the demographic characteristics of the participants, while Section B consisted of multiple choice questions, aimed at ascertaining the participating learners' understanding of mechanics (work, energy, projectile motion and Newton's laws). The TBM was constructed to provide answers to all the research questions. The test was constructed as follows:

- Consisted of two sections; A and B as explained above.
- Section A was about respondents' biographical Information and their preferences regarding instructional and assessment methods, as well as determining their familiarity with, and understanding of, selected concepts in mechanics.

- Section B consisted of Part I and II.
- Part I was about the conceptual difficulties in mechanics and it concerned the first research question.
- Part I, subsection A, concerned the conceptual difficulties in mechanics with regard to 'work and energy'.
- Part I, subsection B, focused on the conceptual difficulties with regard to 'work and energy for motion on inclined planes or surfaces'.
- Part II, sought to reveal learners' alternative conceptions in mechanics and, corresponding to the second research question.
- Part II, subsection A, concerned the alternative conceptions about 'projectile motion'.
- Part II, subsection B, concerned the alternative conceptions about 'force and Newton's laws'.
- Altogether, instrument (pre-test and post-test) consisted of twenty five multiple choice questions.
- For each question there was a space for learners to rate themselves concerning their choices and also a space to motivate their answers. With regard to multiple-choice questions, the results of the study by Pride, Vokos and McDermott (1998) demonstrate that responses to multiple-choice questions often do not give an accurate indication of the level of understanding and that questions that require students to explain their reasoning are necessary. In the same way Kim and Pak (2002:2) state that "responses to multiple-choice questions often do not give an accurate indication of the level of understanding." They further state that "questions that require students to explain their reasoning are necessary" (Kim & Pak, 2002:2).
- Each question carried five marks, that is, two marks for selecting the intended response, one mark for self-rating and two marks for the motivation.
- The total marks on the TBM were one hundred and twenty nine (129) marks.

The questions were based on targeted conceptual difficulties and alternative conceptions from the literature review, possible conceptual difficulties and alternative conceptions identified in the preliminary and pilot studies, as well as potential conceptual difficulties and alternative conceptions which had emerged from learners' responses and problematic notions, from the researcher's experience as a physical science specialist (educator). Therefore, the test did not focus on knowledge, *per se*, but the underlying conceptual understanding. Each multiple choice question was followed by an open-ended question where the answer had to be motivated. Learners had to rate themselves before motivating each answer. The ratings were categorised as "just a blind guess", "not very sure", "fairly sure" and "I'm sure, I'm right".

The aim of the pre-test was primarily to identify further possible conceptual difficulties and alternative conceptions and secondarily to determine the pre-existing knowledge of the participating students. The interventions took these pre-existing alternative conceptions and related information into consideration.

The aim of the post-test was to determine the effectiveness of the respective three interventions. This was done through the determination of whether or not there were statistically significant differences between the pre- and post-test scores of the comparison, the traditional, the OBE and the blended groups, and among the intervention groups.

To serve as motivation for the students to put in an effort to motivate each question properly, an equal number of marks were allocated for students' motivations. For each choice and for each motivation a mark out of two was allocated and one mark for self-rating – giving a total of five marks for each question.

The multiple choice items were not of the single response type. More than one option could be correct. This was made clear to the students. The reason for this was to determine in some questions what the students' most obvious choice was and whether students would be able to identify a more hidden choice.

For content validity the test was validated by the promoter, one physical science lecturer from the University of Zululand and one physical science Subject Advisor from the Empangeni Education District. The feedback received from these experts was used, particularly with regard to content validation – as a result of which, many options were reformulated and rephrased to enhance clarity and remove ambiguity. The test was finalised after analysis of the pilot study for the main study.

As a pre-test it was administered to all the four groups to determine the current level of experience and knowledge of learners with regard to the selected mechanics concepts and principles. The pre-test was also meant to identify conceptual difficulties and alternative conceptions related to selected mechanics concepts and principles. The pre-test was also used to determine the equivalence of the participating groups.

The test was then administered to each experimental group after the interventions (that is, the traditional, OBE and blended approaches) had run their full courses for each respective group. The comparison group was also post-tested. The purpose of the post-test was to identify possible conceptual difficulties and alternative conceptions related to mechanics concepts and principles held by the grade 12 physical science learners, which were resistant to change even after the interventions. Furthermore, the purpose of the post-test was to compare the positive effects of the interventions (traditional, OBE and blended) with regard to the alleviation of conceptual difficulties and alternative conceptions held by learners in mechanics.

The types of questions used in the questionnaire are described in sections 3.8.2 and 3.8.3 below.

### 3.8.2 OPEN-ENDED QUESTIONS

Isaac and Michael (1995:141) say that one of the best ways to developing good objective questions is to administer an open-ended form of question to a small sample of subjects representing the target population of interest. Open-ended questions call for a free response in the respondents' own words. They provide for greater depth of response and require greater effort on the part of the respondent, which makes the return rate to be meager. It's required, therefore, that the researcher formulates the questions in a clear and easy to understand way in order to avoid misinterpretation. The respondent writes how he/she feels about a topic and gives the background of his/her answer.

### 3.8.3 CLOSED QUESTIONS

Best and Kahn (1993:231) define closed questions as questions that call for short, check-mark responses. They are also called structured, restricted or closed-ended question type. They are best for obtaining demographic information and data that can be categorized easily.

The respondent can answer the items more quickly, although somewhat time-consuming for the researcher to categorize. Closed questions sometimes call for a "yes" or "no" answer. It is easy to fill out and take a relatively shorter time to complete. It keeps the respondent on the subject. These Likert-type questionnaires are relatively objective, and fairly easy to tabulate and analyze. The disadvantages of closed questions are:

- Respondents could be forced to choose an alternative that may not be suitable to their situations.

- Construction of closed-ended questions requires, from the researcher, knowledge of the full range of all possible alternatives to a question.

### 3.8.4 VALIDITY AND RELIABILITY OF RESEARCH INSTRUMENTS

There are two concepts that are of critical importance in understanding issues of measurement in social science research, namely validity and reliability (Huysamen, 1989:1-3). Golafshani (2003:597) states that “the use of reliability and validity is common in quantitative research and now it is reconsidered in the qualitative research paradigm”. Golafshani (2003:597) further states that “since reliability and validity are rooted in positivist perspective then they should be redefined for their use in a naturalistic approach”. In this regard, Hoepfl (1997, as cited by Golafshani, 2003:597) posits that “researchers who use logical positivism or quantitative research employ experimental methods and quantitative measures to test hypothetical generalizations”. All too rarely do questionnaire designers deal consciously with the degree of validity and reliability of their instruments (Cooper, 1989:15). Questionnaires have a very limited purpose. They are often one-time data gathering devices with a very short life cycle, administered to a limited population.

There are certain ways to improve both the validity and reliability of questionnaires. Basic to the construct of validity is asking the right questions, phrased in a non-ambiguous way, and to ensure that the items sample a significant aspect of what is intended to be investigated. In this regard, terms should be clearly defined so that they have the same meaning to all respondents (Cohen & Manion, 1989; Cooper, 1989). Concerning quantitative research, Joppe (2000:1 as cited by Golafshani, 2003:599) “provides the following explanation of what validity is in quantitative research: validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are”.

Validity and reliability are especially important in educational research because most of the measurements attempted in this area are obtained indirectly. It is therefore necessary to assess the validity and reliability of these instruments. An educational researcher is expected to include in his/her research report an account of the validity and reliability of the instruments he/she has employed.

#### **3.8.4.1 Validity of the above-mentioned instruments**

Validity is defined by Van Rensburg, Landman and Bodenstein (1994) as the extent to which a measuring instrument satisfies the purpose for which it was constructed. It also refers to the extent to which it correlates with some criterion external to the instrument itself. Validity is that quality of a data-gathering instrument or procedure that enables it to determine what it was designed to determine. In general terms, validity refers to the degree to which an instrument succeeds in measuring what it has set out to measure. Behr (1986) regards validity as an indispensable characteristic of measuring devices.

Dane (1990), Mulder (1989) and Van der Aardweg (1988) distinguish between three different types of validity:

- Content validity is where content and cognitive processes included can be measured; topics, skills and abilities should be prepared and items from each category randomly drawn.
- Criterion validity refers to the relationship between scores on a measuring instrument and an independent variable (criterion) believed to measure directly the behaviour or characteristic in question; the criterion should be relevant, reliable and free from bias and contamination.
- Construct validity the extent to which the test measures a specific trait or construct, for example, intelligence, reasoning, ability, attitudes, etc.

In a nutshell, this means that the validity of a questionnaire indicates how worthwhile a measure is likely to be in a given situation for a particular construct. Validity shows whether the instrument reflects the true story, or at



least sometimes approximating the truth. A valid research instrument is one that has demonstrated that it detects some “real” ability, attitude or prevailing situation that the researcher can identify and characterize (Schnetler, 1993).

The validity of the questionnaire as a research instrument reflects the confidence with which conclusions can be drawn from the results or evidence collected. It refers to the extent to which interpretations of the instrument’s results, other than the ones the researcher wishes to make, can be ruled out or affirmed. Establishing validity requires that the researcher anticipate the potential arguments that skeptics might use to dismiss the research results (Cooper, 1989; Dane, 1990).

In terms of measurement procedures, therefore, it is the ability of an instrument to measure what it is designed to measure. Validity is defined as the degree to which the researcher has measured what he has set out to measure (Smith, 1991: 106). This definition raises some questions:

- Who decides that an instrument is measuring what it is supposed to measure?
- How can it be established that an instrument is measuring what it is supposed to measure?

Obviously, the answer to the first question is the person who has designed the study and experts in the field. The second question is extremely important. In the social sciences there appear to be two approaches to establishing the validity of a research instrument: logic and statistical evidence. Establishing validity through logic implies justification of each question in relation to the objectives of the study, whereas the statistical procedures provide hard evidence by way of calculating the coefficient of correlations between the questions and the outcome variables (Kumar, 2005).

There are various types of validity, namely, face, content, predictive, concurrent and construct validity (Imenda & muyangwa, 2006). These are briefly explained below.

### **Face and Content Validity**

Face validity is the extent to which, on the surface, an instrument looks like it is measuring a particular characteristic. Face validity is often useful for ensuring the cooperation of people who are participating in a research study. However, because it relies entirely on subjective judgment, it is not, in and of itself, terribly convincing that an instrument is truly measuring what the researcher wants to measure (Leedy & Ormrod, 2005). The judgment that an instrument is measuring what it is supposed to measure is primarily based upon the logical link between the questions and the objective of the study (Kumar, 2005).

Content validity refers to the extent to which the content of interest has been covered by a particular measurement (Imenda & Muyangwa, 2006; Leedy & Ormrod, 2005). The study of content validity concerns sampling procedures followed to construct or select questions to constitute a given instrument. Content validity is also judged on the basis of the extent to which statements or questions represent the issue they are supposed to measure, as judged by a researcher and experts in the field (Kumar, 2005).

Because of the complexity of the reactions of an individual to a stimulus, it is extremely difficult in the social sciences (including education) to develop valid and reliable measurement instruments to ascertain changes in the attributes of interest to the researcher (Imenda & Muyangwa, 2006; as cited by Coetzee, 2008:84). Nonetheless, the researcher made attempts to validate the instruments.

For validity purposes, the researcher submitted the research instruments (Appendices A, B, C and D) to the promoter, Professor S.N. Imenda, the

Executive Dean: Faculty of Education, University of Zululand. As an expert in the field of Science Education, he went through the research instruments of this study. He looked at grammar, wording and the structure of the instruments (face and content validity). He made comments on the instruments for the attention of the researcher. The researcher attended to the comments and made changes to the instruments. As a Science Education specialist, the promoter attended to the content of each instrument to ensure that it fell in line with the objectives of the study. The promoter, therefore, then ascertained that the content of the instruments had been adequately covered by the instruments (Imenda & Muyangwa 2006). Furthermore, the instruments were also cross-validated by two physical science educators (both Heads of Departments) from two schools that were not selected for participation in the study. Their comments were also used to improve the instruments.

The test was further examined by two physical science specialists and two physical science subject advisors. This process was done in order to establish content and face validity, to clear out misunderstandings or misleading and ambiguous texts. The linguistic complexity of the text was also investigated to make sure it was not beyond the understanding of the grade 12 learners. The pilot test was done and the test was also proof read by two colleagues before pilot test. Some corrections were made to the test before the main study commenced.

#### **3.8.4.2 Reliability of Instruments Used in this Research Study**

According to Mulder (1990:209) and Van Rensburg, *et al* (1988) reliability is a statistical concept and relates to consistency and dependability. Kumar (2005) states that “if a research tool is consistent and stable, and, hence, predictable and accurate, it is said to be reliable”. Kumar (2005:157) further maintains that “in social sciences it is impossible to have a research tool which is 100 per cent accurate, not only because a research instrument cannot be so, but because it is impossible to control the factors affecting reliability”. Such factors include the

wording of questions, the physical setting in case of interviews, the respondent's mood, the nature of interaction, and the regression effect of an instrument (Kumar, 2005). Consistency refers to the constancy of obtaining the same relative answer when measuring phenomena that have not changed (Rensburg, *et al*, 1988). A reliable measuring instrument is one that, if repeated under similar conditions, presents the same result or a near approximation of the initial result. Van der Aardweg (1988) and Kidder and Judd (1988) distinguish between the following ways of establishing reliability:

- Test-retest reliability (co-efficient of stability) – estimated by comparing two or more repeated administrations of the reassuring instrument. This gives an indication of the dependability of the results on one occasion and on another occasion.
- Internal consistency reliability. This indicates how well the test items measure the same thing.
- Split-half reliability. By correlating the results obtained from two halves of the same measuring instrument, we can calculate the split-half reliability coefficient.

In essence, reliability refers to consistency, but, consistency does not guarantee truthfulness. The reliability of the question is no proof that the answers given reflect the respondents' true feelings (Dane, 1990). Thus, a demonstration of reliability is necessary but not conclusive evidence that the instrument is valid. This is so because reliability refers to the extent to which measurement results are free of unpredictable kinds of error. Sources of error that affect reliability are, *inter alia*, the following (Mulder, 1989; Kiider & Judd 1986):

- Fluctuations in the mood or alertness of respondents because of illness, fatigue, recent good or bad experiences, or temporary differences amongst members of the group being measured.
- Variations in the conditions of administration between groups. These range from various distractions, such as unusual outside noise to

inconsistencies in the administration of the measuring instrument, such as omissions in verbal instructions.

- Differences in scoring or interpretation of results, chance differences in what the observer notices and errors in computing scores.
- Random effects by respondents who guess or check off attitude alternatives without trying to understand them.

To ensure reliability in qualitative research, examination of trustworthiness is crucial. Seale (1999), while establishing good quality studies through reliability and validity in qualitative research, states that the 'trustworthiness of a research report lies at the heart of issues conventionally discussed as validity and reliability'. Golafshani (2003:601) asserts that "the difference in purposes of evaluating the quality of studies in quantitative and qualitative research is one of the reasons that the concept of reliability is irrelevant in qualitative research". According to Stenbacka (2001) "the concept of reliability is even misleading in qualitative research". Furthermore, Stenbacka (2001) argues that since reliability issues concern consistency of measurements then they have no relevance in qualitative research. She adds that the issue of reliability is an irrelevant matter in the judgment of quality of qualitative research. Therefore, if it is used then the 'consequence is rather that the study is no good' (Stenbacka, 2001). Lincoln and Guba (1985:316) argue that "since there can be no validity without reliability, a demonstration of the former (validity) is sufficient to establish the latter (reliability)". Panton (2001) contends that with regard to the researcher's ability and skill in any qualitative research that reliability becomes a consequence of the validity in a study. In this regard, Healy and Perry (2000) assert that "the quality of a study in each paradigm should be judged by its own paradigm's terms". In support of Healy and Perry, Lincoln and Guba (1985 as cited by Golafshani, 2003:601) posit that

the terms Reliability and Validity are essential criteria for quantitative paradigms, in qualitative paradigms terms Credibility, Neutrality or Conformability, Consistency or Dependability and Applicability or Transferability are to be essential criteria for quality".

To be more specific, qualitative research, construes the notion of “dependability”, in qualitative research as closely corresponding to “reliability” as applied to quantitative research (Lincoln & Guba, 1985). Golafshani (2003:601) avers that “to ensure reliability in qualitative research, examination of trustworthiness is, therefore, crucial”. Coetzee (2008) also opine that a good research depends to a large degree upon the reliability (consistency) and validity (precision) of the instrument used to collect data, and the ability to accurately measure the variables of interest, that is dependent and dependent variables. By way of definition, Coetzee (2008:122) further refers to reliability as “the consistency of measure, which describes the extent to which a given instrument or procedure yields the same results for all students who possess the same amount and quality of a given attribute”.

The determination of alternative conceptions was done through analysis of qualitative data. The research instruments were therefore meant to gather the qualitative data. Learners had to motivate their choices in the pretest and posttest instruments. The motivations were then considered to be a reliable measure of the learners’ understanding – more than assumptions drawn simply on the basis of the learners’ choices from multiple choice tests. Learners’ motivations were categorised as conceptual difficulties, when learners presented evidence of a conceptual difficulty and their motivations were also categorised as alternative conceptions, when learners presented evidence of an alternative conception. In this regard, only responses which directly addressed a certain category were categorised. In the same way, uncertainties were categorised as ‘not applicable’, which included wrong statements and statements of no use.

### **3.9 INSTRUCTIONAL INTERVENTIONS**

The three instructional interventions (traditional, OBE and blended) are described and they concern the third research question. Imenda (2002a, as cited by Coetzee, 2008) identifies three perspectives in the history of curriculum development and the three perspectives are: inputs perspective, process perspective and outcomes perspective. The development of the interventions took the balance among the inputs (content and alternative conceptions), process (instructional methods and quality of learning experiences) and outcomes (the skills and competences the learner needed to demonstrate as a result of specific instructional interventions) into consideration. Nonetheless, it was also realised that it takes time for learners to achieve conceptual change (Coetzee, 2008).

The knowledge area “mechanics” had been selected to be investigated for this study because this is a topic area where there is evidence of particular learning difficulties, whereas it is an important part of the grade 12 physical sciences curriculum. An intervention programme was followed over a period of two weeks. The four groups wrote identical tests (TBM), simultaneously, under the same conditions. The post-test was written two weeks after the pre-test. The difference in the individual scores between pre- and post-testing was compared to determine the effectiveness of the respective interventions. The researcher was the teacher for the three intervention groups.

#### **3.9.1 TRADITIONAL APPROACH INTERVENTION**

For the traditional group, the concepts were treated in the traditional way of teaching, where the teacher stands at the front of the classroom and the students sit at their desks. Lecturing or telling method and use of only the prescribed textbook as reference material were the dominant instructional approaches. The intervention was almost teacher centred and the students were most of the time

passive recipients. There was little or no interaction and communication amongst students, and with the teacher, took place, although the teacher made use of questions sometimes to check students' attention. The teacher remained in complete control of class proceedings.

A variety of instructional methods were used to compensate for student diversity and to keep the students active during the lecture. Driver and Oldham (1986), state that "listening, talking or reading can involve active participation by the learner when making connections between aspects of that situation and his/her prior knowledge". With regard to lecturing, Bligh (2000) makes recommendations to make large lecture settings more interactive. Some of these recommendations are the following:

- capture the key points of the lecture in notes with the help of the white/black board and the overhead projector;
- obtain verbal feedback by the questioning technique, although the questions are asked by the educator and not by the learners;
- obtain non-verbal feedback from observation of the students' reactions;
- make eye-contact with the learners;
- promote student thought by individual problem solving;
- use a variety of methods to cater for the individual differences and preferences;
- make the lecture meaningful to the students and take the alternative conceptions into consideration;
- repetition consolidates learning;
- enthusiasm from the lecturer;
- relevance to their careers by means of applications.

Bligh's (2000) golden rule with regard to traditional approach is to vary the presentation. Coetzee (2008:164) maintains that lecturing or telling method "is still the best way to transmit information, although it does not very effectively promote understanding". Coetzee further posits that "the outcomes of student



learning can be improved in large lecture settings by implementing interactive learning strategies by means of individual participation and peer learning during the lecture process”.

In keeping with the aim of this study, this intervention entailed the application of the traditional lecture approach as described above. Therefore, the interactive learning strategies were limited. During the intervention the conceptual difficulties and alternative conceptions were directly addressed.

### 3.9.2 OBE APPROACH INTERVENTION

For the OBE group the concepts were treated according to an OBE approach, based on the constructivist way of teaching and learning. Instruction also focused on the pre-identified conceptual difficulties and alternative conceptions. Learners' questions, comments, responses in tests and during class were used. Instruction involved an open interaction between the educator and the learners, as well as learner-learner interactions.

The researcher used intervention strategies which adhere to the notion of constructivism in the OBE intervention. The constructivist approach focuses on quality over quantity (Mintzes, et al, 1998:327). Gray (1997) also posits that constructivism uses a process approach, focusing on the ideas which are allowed to develop in the learner's own mind through a series of activities. According to the constructivist view, for learners to develop an understanding of the conventional concepts and principles of science, more is required than simply providing practical experiences. More guidance is needed to help learners assimilate their practical experiences into what is possibly a new way of thinking about them (Driver, 1983).

A variety of instructional methods used during the intervention for the OBE group involved interactive student-centred methods. Learners' questions, comments, responses on tests and work at the chalk board were used. Learners' answers

were probed to identify the reason the learners gave for their answers. The students participated fully in the programme through the following activities: handing in assignments; giving feedback by use of transparencies on the overhead projector; controlled class discussions; negotiating meaning in small discussion groups; hands-on activities; individual problem solving tasks; articulating relevant personal experiences; and wrestling with real world problems rather than memorising answers.

The teacher played the role of a facilitator. The approach of the facilitator centred on ascertaining what the learners already knew, and organising instruction that built on that knowledge. Application of real-life situations was central, and individuality was accommodated as far as possible. The variety of instructional methods compensated for student diversity. Understanding was assessed by means of different continuous assessment assignments. Peer and self-assessment modalities were also used.

Students were encouraged to use other sources in addition to the prescribed textbook, e.g. reference lists of similar textbooks in the library, lecture material, notes, internet, consultations with physical science educators and other educators and peers.

The pre-identified conceptual difficulties and alternative conceptions were directly addressed during the activities of the intervention. The activities aimed at encouraging learners to construct scientific ideas for themselves, and challenge their pre-existing conceptions.

In this study, time was a limiting factor for the OBE and the blended interventions. Even the time interval of four weeks between the pre-test and the post-test was a limiting factor which could have influenced the results.

The activities of the OBE intervention are described below:

- The outcomes of this instructional intervention and the applications in the students' fields of study on mechanics were outlined at the onset and in class at the start of the intervention. Previously identified alternative conceptions were included in the questions.
- Each group gave feedback and made use of the overhead projector (groups were issued with transparencies and pens to summarise their consensus answers). The groups were encouraged to make notes to comment on the different groups' feedback.
- Class discussions followed; the educator chaired the discussions, but didn't take part.
- Demonstrations on projectile motion controlled by the educator were performed at applicable times during class discussions.
- A peer-controlled group assignment on work and energy followed.
- An individual self evaluation with multiple choice questions followed.
- The intervention ended with a short discussion, controlled by the educator.

During the individual pre-reading homework assignment students were asked to explore their conceptions. Conflicts between individuals were discussed and ideas were exchanged in the groups. Spontaneous disagreement among students, unexpected demonstrations by the educator and the different activities, which included the construction and use of multiple choice test, led to construction of new ideas. The educator consolidated and reinforced the new conceptions and learners had the opportunity to reflect on their new ideas.

### 3.9.3 BLENDED APPROACH INTERVENTION

Using the blended intervention (Appendix E), the concepts and principles were treated according to the blended approach to teaching and learning. Blended learning is used to describe learning that mixes various event-based activities: self-paced learning, live e-learning and face-to-face classrooms. An efficient blended learning programme includes a mixture of these three learning types (Alonso, Lopez, Manrique & Vines, 2005). According to Alonso, *et al*, (2005), blended learning combines training, coaching, and self help. In the present study, this approach used a variety of teaching and learning strategies to further clarify mechanics concepts and principles. Instruction focused on pre-identified conceptual difficulties and alternative conceptions. Instruction further involved face-to-face classroom (traditional way of teaching), open interaction between the educator and the learners, interactions among learners themselves, computer-mediated teaching and learning and co-operative learning. A continuum of teaching strategies was used in the clarification of mechanics concepts and principles.

Against this background, it was important for the researcher to look at the principles that determine whether a questionnaire, pre-tests, post-tests and interventions are well designed thereby drawing a distinction between the content, question format, question order, type of questions, formulation of questions, as well as the validity and reliability of questions.

The traditional approach to teaching and learning is mainly dominated by lecture or telling method and memorisation by learners. The teacher is the disseminator of information. For its part, the OBE approach to teaching and learning is dominated by group discussions and the educator is regarded as the facilitator of learning. With regard to blended approach, all teaching strategies and methods are vitally important since in a class of learners there are different learners'

characteristics with different learning styles. According to Jacobs, Gawe and Vakalisa (2002), a teaching strategy includes:

- The methods, procedures, activities and techniques the teacher uses to help learners understand the learning content;
- Learner activities; and
- The teaching media which will be used.

By way of definition, a teaching method is the way in which one conveys certain lesson contents to a certain class (Kruger & Schalkwyk, 1997). Kruger and Schalkwyk (1997: 96) further refer to teaching methods “as strategies, techniques and modes of instruction”. They further posit that various teaching methods may be used within one lesson period. According to Kruger and Schalkwyk (1997:96) “in practice, there are three basic teaching strategies, each with its own specific teaching methods:

- Demonstrative teaching strategy (presentation), and this teaching strategy includes narrating, lecture, speech and demonstration methods;
- Interactive teaching strategy (Discussion), and this teaching strategy includes teaching-learning, discussion, class discussion and group work methods; and
- Self-discovering (self-activities), and this teaching strategy includes games, projects, worksheets/charts and fieldwork methods.

As stated previously, blended learning combines or mixes various event-based activities, including face-to-face classroom interactions, live e-learning and self-paced learning (Valiathan, 2002). In the same way, Gravett and Geyser (2004) opine that blended learning employs multiple strategies, methods, and delivery systems which combine the best features of online learning with the best features of classroom instruction. The educator becomes the facilitator of learning, and his/her role may alternate between that of mentor, organiser, sage, knowledge broker, moderator, and also fellow learner.

As it was explained in chapter two, Driscoll (2001) points out that blended learning may be understood by different people as to refer to the following concepts:

- To combine or mix modes of web-based technology (e.g., live virtual classroom, self-paced instruction, collaborative learning, streaming video, audio, and text) to accomplish an educational goal.
- To combine various pedagogical approaches (e.g., constructivism, behaviourism, cognitivism) to produce an optimal learning outcome with or without instructional technology.
- To combine any form of instructional technology (e.g., videotape, CD-ROM, web-based training, film) with face-to-face instructor-led training.
- To mix or combine technology with actual job tasks in order to create a harmonious effect of learning and working.

To accommodate learners' various learning styles, the researcher used a continuum in the methods of teaching, especially with the blended group, knowing that a class of learners is composed of different learner characteristics. To be more precise the teaching strategies and activities with the blended group were run as follows:

- Lecture method was used in which the educator was the only one talking with learners being quiet and listening. Imenda (2010:3) maintains that "lecture still remains an important way to communicate information". The researcher used the lecture method to introduce mechanics topics (work, energy, projectile motion, force and Newton's laws) during the blended intervention. The lecture method was also used to explain alternative conceptions and difficult mechanics concepts discovered during pre-testing. The lecture was best used to gain the attention of the learners, elicit learner participation in some activities, and provide feedback and positive re-enforcement; and also to obtain feedback from the learners.

- Demonstration: the educator performed demonstrations based on projectile motion, force and Newton's laws.
- Question and answer: with regard to this approach the educator asked questions and learners took turns to give answers.
- Group discussions: during small group discussions, learners were given tasks to discuss among themselves; the educator was available to facilitate, receive and give feedback.
- Each group gave feedback and made use of the overhead projector (groups were issued with transparencies and pens to summarise their consensus answers). The other groups were encouraged to make notes to comment on different groups' feedback.
- Class discussions followed. The teacher chaired the discussions, but did not take part in the discussions. Learners were given time to learn from each others' ideas.
- Worksheet-based activities on work, energy, projectile motion, force and Newton's laws had been prepared and also used. This was individual learner work aimed at checking understanding of concepts. These worksheet-based activities were peer-controlled (marked). The educator then led the class discussions for corrections.
- Watching videotape: learners watched demonstrations based on Newton's Laws of motion as a substitute for laboratory experimental demonstrations due to the scarcity of laboratory equipment in the participating school. Question and answer method then followed to check understanding of the demonstrations.
- An individually-based self evaluation test with multiple choice questions based on Newton's Laws followed.

- Watching animations of projectile motion using the data projector. Learners were given an opportunity to observe the behaviour of particles (projectiles) with special reference to position, velocity and acceleration. This was done to eliminate alternative conceptions held by learners regarding projectile motion.
- Web-based learning followed where the classroom was changed to a networked electronic environment using a laptop, modem and data projector. This facility was only used by the educator (researcher) with learners watching the screen. Mechanics concepts relating to work, energy and power; projectile motion; force and Newton's Laws were searched through the Internet using Google scholar.
- Self-paced instruction: learners were then encouraged to search through the Internet for mechanics concepts relating to work, energy and power; projectile motion; force and Newton's Laws using their cell phones or computers at home (homework assignment). Learners were given the list of concepts about which to gather information.
- Group discussion: learners were given the opportunity to share information and ask questions of one another and of the teacher regarding what they learnt from self-paced learning. The discussion ended as a class discussion in which the teacher led the discussion in order to give direction and clarity on some concepts. In this way, knowledge was constructed by learners.

In chapter two, self-paced learning was described as what the learner does by executing the e-learning process, and self-paced activities can be taken at the learner's leisure, that is, can be taken anytime and any where. Learners integrated new ideas with prior knowledge in order to make sense or make meaning. Learners engaged in mindful processing of information where they



were responsible for the results. Through the use of cell phone, learners were indirectly taught how to use cell phones meaningfully and for themselves to benefit academically.

It was not possible for all the teaching strategies to be used in one lesson. Strategies used had to depend on the nature and requirements of the particular lesson outcomes.

### **3.10 PILOT STUDY**

A pilot study is a preliminary or “trial run” investigation using similar questions and similar subjects as in the final study. A pilot study was carried out during the second half of 2010, to see if the proposed direction of the study was viable. The pilot sample consisted of 140 grade 12 physical science learners from a high school in the Lower Umfolozi Education Circuit. The group of 140 learners was further divided into four (4) groups of 35 learners each. The groups were divided as follows:

- Group 1 : OBE intervention;
- Group 2 : Traditional intervention;
- Group 3 : Blended intervention; and
- Group 4 : Comparison Group.

Group 4 was taken as a control or comparison group while the first three groups were taken as experimental (treatment) groups. A trial run of the TBM (earlier version of appendix A) was administered to the pilot sample of physical science learners in a school that was not selected for participation in the study. The basic purpose of the pilot study was to determine how the design of the subsequent study could be improved and to identify flaws in the measuring instrument (Kidder & Judd, 1986). In this respect, the pilot study provided the researcher with an idea of how well the main study would run with regard to the

grouping of subjects, the interventions and instrument. Typically, practical problems that arise during the pilot study enable the researcher to avert these problems by making improvements to the procedures, instructions and questions – as the case may be.

According to De Vaus (1990: 105) a pilot study has various advantages, which prompted the researcher to use it in this project. These advantages, amongst others, are that it:

- permits a thorough check of the planned statistical and analytical procedures, thus allowing an appraisal of their adequacy in treating data.
- provides the research worker with ideas, approaches and clues not foreseen prior to the pilot study. Such ideas and clues greatly increase the chances of obtaining clear-cut findings in the main study.

According to Plug, Meyer, Louw and Gouws (1991: 49-66) the following are the purposes of a pilot study, and these were also taken cognisance of by the researcher in the present investigation.

- It greatly reduces the number of treatment errors in the sense that unforeseen problems revealed in the pilot study are then used to redesign the main study.
- It saves the researcher major expenditures of time and money on aspects of the research that may have been unnecessary.
- Feedback from other persons involved is possible, leading to important improvements in the main study.
- In the pilot study, the researcher tries out a number of alternative measures and selects only those that produce the best results for the final study.
- The approximate times required to complete the questionnaire and the tests were established in the pilot study.

- Questions and/or instructions that are misinterpreted are reformulated.

The researcher also considered the following as the aims of the pilot study as stated by Coetzee (2008):

- To identify unsuitable and unclear items in the instruments;
- To identify pre-knowledge, possible conceptual difficulties and alternative conceptions;
- To have a prior test run for the intervention and to learn from the pilot study; and
- To establish equivalence of participating groups.

Quite importantly, in order to identify the weaknesses in the research instrument (the TBM) for ambiguity and clarity of wording, it was necessary to conduct a pilot study. Thus, the pilot study served as a trial run for the final administration of the TBM.

The results of the pilot study suggested that a few changes were necessary. Some of these items had to be reworded after some learners left out some of the crucial questions. Indeed, this trial run proved to be invaluable in refining the instrument. Through the utilisation of the pilot study, the researcher was satisfied that the questions asked in the TBM complied adequately with the requirements of the study.

The most prevalent conceptual difficulties and alternative conceptions identified in the pilot study and literature were incorporated into the development of the interventions. The three interventions focused explicitly on these conceptual difficulties and alternative conceptions. To be precise, the interventions concerned the following mechanics topics:

- Work and energy;
- Projectile motion; and
- Force and Newton's laws.

Some of the conceptual difficulties with regard to **work and energy** identified during the pilot study are outlined below. For instance, learners had some difficulty with the understanding of mechanics concepts and problem-solving. Their comments, statements and motivations are given in italics. Conceptual difficulties were:

- In calculating the components of force with the use of the concept of the “components of vectors” in order to determine the work done by a force exerted at an angle  $\theta$  to the horizontal. Questions 1, 5, 6, 8, 9, 10, 11, 12, 14 and 15 from Section B, Part I of the (TBM) were mainly problem solving prior to choosing the correct option. Most of these questions were based on motion on inclined surfaces. Learners were having difficulty in using the components of the weight to solve problems in order to arrive at the correct option.
- In calculating the work done by friction using  $W_f = F_f \cdot \Delta x \cos 180^\circ$ . Learners were unable to recognise that the angle between frictional force ( $F_f$ ) and change in position  $\Delta x$  was  $180^\circ$ .

The following were learners’ comments in this regard:

*I failed to recall the formula.*

*I have no idea.*

*I failed to remember the equation.*

*I failed to do calculations which were going to prove this to me.*

Learners mostly relied on formulae and lacked conceptual understanding. In this regard, John (1987:2) avers that

while taking physics many students can be described as ‘formula centred’ both in their knowledge of physics and in their approach to problem solving. They are able to solve some problems that require only plugging numbers

into formulas and manipulating those formulas, but are still unable to solve some very basic qualitative problems.

Learners need to understand concepts more than knowing formulae.

- In applying the work-energy theorem. With regard to this theorem some of the learners made the following comment:

*The work done on an object by a net force is equal to the kinetic energy of the object.*

To learners, the above statement was regarded as correct. According to Giancoli (2000:129), the work-energy theorem can be stated as follows: “The net work done on an object is equal to its change in kinetic energy.” Giancoli (2000:129) further states that the work-energy theorem is valid only if ‘w,’ for work, is the net work done on the object “. Learners missed out key words here “change in kinetic energy”, not just kinetic energy. This indicates that they had not by then understood the the work-energy theorem as a concept. Lack of understanding of this (work-energy) concept, would also lead to poor application of the theorem by the learner respondents.

Some of the alternative conceptions with regard to **projectile motion** identified during pilot study are also outlined below. Learners had the following alternative conceptions with regard to projectile motion: (learners’ comments, statements and motivations are given in italics.)

- *Acceleration and velocity are always in the same direction for a projectile thrown vertically upwards.*
- *A vertically thrown object has zero acceleration at the highest point.*
- *When a stone is thrown upwards, there is an increase in position and when the stone returns down the position decreases.*

- *When a stone goes up there is a decrease in velocity and also in acceleration.*
- *The velocity of the ball increases as it moves vertically upwards.*
- *I think the acceleration of the ball increases as the ball moves upwards.*

With regard to projectile motion, the following can be noted: Projectiles in motion have zero velocity at their greatest height and take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch. The acceleration due to gravity is always downwards and constant. By way of definition, gravitational acceleration is the constant acceleration that a free falling object experiences due to gravitational attraction of the earth in the absence of air resistance, whether the object is moving upwards or downwards. The symbol is  $g$  and the value is  $9,8 \text{ m.s}^{-2}$  downwards. Bueche (1986) maintains that like all other accelerations, the acceleration due to gravity is a vector that is directed downwards towards the centre of the earth. Bueche (1986) further states that “falling objects speed up and rising objects slow down.” Therefore, the velocity of a stone thrown vertically upward will decrease due to negative acceleration. According to Giancoli (2000:53) “projectile motion refers to the motion of object that is projected into the air at an angle.” The effects of air resistance are often ignored. One of the alternative conception stated above (as bullet number three), was that learners would think that as the stone is thrown vertically upwards, the *position increases*. The *position* of the projectile does not *increase* nor *decrease* but it *changes the position*, that is, from one point to another. Learners lacked the proper use of scientific language in this regard.

Alternative conceptions with regard to **force and Newton’s Laws** identified during pilot study were outlined as follows: (Learners’ comments, statements and motivations are given in italics.)

- *Force is any applied strength that keeps the object in motion.*
- *Force is energy acting on an object to give it or get it to motion.*

- *Action and reaction forces are not exerted simultaneously.*
- *A force is needed to keep an object moving including objects that have zero resultant force acting on them.*
- *A force is needed to keep an object moving at all times.*
- *Force is same as pressure.*
- *With regard to Newton's Third Law, action reaction forces: Both forces are exerted at different times on different objects.*
- *The wall exerts a force back on the goat which is larger than the goat's force on the wall*
- *Only the monument is exerting a force..*

With regard to Newton's Third Law, the law states that when pairs of objects interact they exert forces on each other. These forces are equal in size and point in opposite directions. According to Newton's Third Law of motion, a Force Pair:

- Will be the same size but in opposite directions;
- Work along the same line;
- Exert a force on two objects;
- Will be of the same force type; and
- Will be exerted at the same time.

Learners are likely to confuse Newton's First Law with Newton's Third Law in that some aspects sound common. For example, both laws do involve forces of the same size but in opposite directions. The difference is that in Newton's First Law the forces are exerted on the same object whereas in the Third Law the forces are exerted on two different objects.

Regarding Newton's Third Law, Brown and Clement (1987) state that the law is about action-reaction pair of force but it really makes no difference which force you call the action and which the reaction, because they occur at exactly the same time.

### **3.11 DATA COLLECTION PROCEDURES**

Physical science is also the subject of the researcher's specialisation and interest. The TBM was given to learners to write. The researcher explained questions or concepts that may have been unfamiliar to the learners since English was their second or weaker language, which they only used at school, thus making their command of the language still on a developmental trajectory.

The researcher personally visited the four (4) schools to do the three interventions (traditional, OBE, and blended interventions). Pre-tests were administered to all the four groups.

### **3.12 DATA ANALYSIS TECHNIQUES AND PROCEDURES**

The data collected through pre-tests, post-tests as well as through learners' comments were then analysed. The researcher had to go through all the information collected and organised it according to the research questions, hypotheses and/or objectives that were to be addressed. The researcher then identified the data analysis technique to be employed in data analysis. In this regard, the researcher went through the collected information manually and created themes or categories of information on the basis of response patterns which emerged (Imenda & Muyangwa, 2006). Once data were collected, they were captured in a format which permitted analysis and interpretation. This involved the careful coding of the 140 pre-test responses and as well as 140 post-test responses completed by grade 12 physical science learners. The coded data were subsequently transferred onto a computer spreadsheet.

The data-analysis technique was a combination of:

- quantitative analysis of the multiple choice answers, followed by statistical testing, and



- qualitative analysis by the researcher which involved the interpretation and categorisation of the learner motivations.

The data were then related to the research questions and hypotheses.

### 3.12.1 QUANTITATIVE ANALYSIS

Section A of the TBM yielded biographical information as well as students' preferences regarding teaching methods, especially their opinions about OBE. During both pre- and post-testing, students were required to motivate each choice. Choices were analysed quantitatively and the open-ended motivations both quantitatively (frequencies) and qualitatively. The researcher felt that the open-ended questions would elicit more original responses and enough information on alternative conceptions. The rubric for choices for the BMT was designed as follows:

Rubric for choice:

MARK	Description
0	No choice Wrong choice A correct choice was cancelled by a wrong choice.
2	Correct choice.

The rubric for self-rating was designed as follows:

Rubric for self-rating:

Mark	Description
0	No rating at all
1	Any rating

The rubric for learner motivation was also designed as follows:

Rubric for motivation:

MARK	
0	No remark
1	Remark of a few words which indicate no idea, e.g. "I am totally confused". Any attempt to write something which makes no sense.
2	More comprehensive motivation, which makes sense OR valid motivation.

### 3.12.2 QUALITATIVE ANALYSIS

During qualitative data analysis the researcher looked for statements, meanings, descriptions and interpretations of the students' experiences and constructed categories for alternative conceptions from the students' statements in the open-ended motivations. These categories emerged progressively from the data as the analysis proceeded.

The categories and frequencies of the alternative conceptions of the pre- and post-test results were compared to determine the prevalence of the alternative conceptions held by the students.

The procedure for the qualitative analysis is summarised as follows:

- (i) In both the pre- and post-tests, each motivation was analysed and alternative conceptions were identified and categorised.
- (ii) To illustrate how ideas unfolded for each question, different responses of individuals were listed.
- (iii) From the pre-test, the most prevalent alternative conceptions on different questions were identified.
- (iv) From the post-test, the most prevalent alternative conceptions on different questions still held by learners were also identified.

- (v) The most prevalent conceptual difficulties from both the pre- and post-tests were also identified and documented.

### 3.12.3 STATISTICAL ANALYSIS

The scores of the participating students were statistically analysed in accordance with the research hypotheses.

Research hypotheses:

- An intervention based on the traditional instructional approach has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- An OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- A Blended instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions in mechanics.
- There is no statistically significant difference amongst OBE-based, traditional and blended instructional interventions in alleviating the conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.
- Test of significant among all the four groups on the posttest.

The researcher considered the following statistical type of analysis as the best to ascertain the effectiveness of the three interventions, that is, One Way Analysis of variance (ANOVA).

According to the BMA Informa Health Care (2009:1), “analysis of variance, also known as ANOVA, is perhaps the most powerful statistical tool. ANOVA is a general method of analysing data from designed experiments, whose objective is to compare two or more group means”. By way of description, “a one-way ANOVA is a way to test the quality of three or more means at one time by using variances”. This study involved or consisted of four groups including the comparison group. Designed experiments refer to experiments with a particular structure; and well designed experiments are usually optimal with respect to meeting study objectives (BMA Informa Health Care, 2009). Wikipedia, the free encyclopedia describes ANOVA as a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components due to different sources of variation.

Willemse (1994:173) posits that

The analysis of variance technique tests the hypothesis that more than two samples have the same means. It is also possible to use ANOVA for a small sample situation, since the F-distribution changes according to the number of degrees of freedom.

With regard to the use of ANOVA, a number of experimental units are subject to a number of treatments each at a number of levels (Muchengetwa, 2009).

Muchengetwa (2009:121) further states that “sometimes there are other factors present, called blocking factors, which divide the experimental units into groups which are more uniform (before the experiment starts) than all the units jointly”. Furthermore, Muchengetwa (2009:121) avers that

After one or more treatments have been applied to such groups of experimental units, the result is observed. This result is called the yield.... The purpose of the analysis of variance is to test whether the treatment had an effect on the yield, and sometimes whether the groups defined by the blocking factors differ with respect to yield.

Wikipedia (2010:1), the free encyclopedia states that “in its simplest form ANOVA provides a statistical test of whether or not the means of several groups are equal... ANOVAs are useful in comparing three or more means”. Based on this statement, researcher chose ANOVA since the study involved four groups (traditional, OBE, blended and comparison) for which their means had to be compared. Wikipedia (2010:1) further states that

One-way ANOVA is used to test for differences among two or more independent gorups. Typically, however, the one-way ANOVA is used to test for differences among at least three groups, since the two-group case can be covered by a t-test.

Cohen, Manion and Morrison (2007), state that the t-test is useful for examining the differences between two groups of respondents. The respondents in each sample group were more than thirty (30) and therefore, the z-test was mostly preferred than the t-test. The z-test was used to compare two groups at a time to further ascertain the effectiveness of the interventions.

With regard to this study, the treatments were the traditional, OBE and the blended interventions. The study therefore compared three interventions.

### **3.13 ETHICAL CONSIDERATIONS**

This study focused on conceptual difficulties and alternative conceptions held by grade 12 physical science learners in Empangeni Education District. In this regard, the researcher bore in mind that whenever human beings are the focus of investigation, ethical implications of what is proposed to be done should be considered (Leedy, 2005). According to Leedy (2005:101), “most ethical issues in research fall into one of the four categories: protection from harm, informed consent, right to privacy, and honesty with professional colleagues”. The researcher therefore addressed the ethical issues involved and those concerning participants in the following manner:

**Collecting information:** The researcher considered the relevance and usefulness of the research he undertook to avoid wasting the respondents' time since it would have been unethical to do so (Kumar, 2005:212). He also ensured that respondents were fully convinced of the relevance and usefulness of the research study. Certainly, the researcher countenanced no harm that could have afflicted the participants in this research.

**Seeking consent:** According to Kumar (2005), it is considered unethical to collect information without the knowledge of participants, and their expressed willingness and informed consent. Consequently, seeking informed consent "is probably the most common method in medical and social research" (Bailey, 1978: 384). Informed consent implies that subjects are made adequately aware of the type of information wanted from them, why the information is being sought, what purpose it will be put to, how they are expected to participate in the study and how it will directly or indirectly affect them (Kumar, 2005). Kumar (2005:212) further states that "it is important that the consent should be voluntary and without pressure of any kind".

On their part, Schinke and Gilchrist (1993:83) opine that

Under standards set by the National Commission for the Protection of Human Subjects, all informed-consent procedures must meet three criteria: participants must be competent to give consent; sufficient information must be provided to allow for a reasoned decision; and consent must be voluntary and uncoerced.

Competency, according to Schinke and Gilchrist (1993:83), "is concerned with the legal and mental capacities of participants to give permission". For example, some very old people, such as those suffering from conditions that exclude them from making informed decisions, people in crisis, people who cannot speak the language in which the research is being carried out, people who are dependent upon others for a service and children are not considered competent (Kumar, 2005).

In order to comply with the various ethical requirements enunciated above, the researcher therefore wrote a letter to principals (Appendix F4) of the participating schools at Empangeni Education District, requesting them to participate in the study. It was mentioned that participation in this study was strictly voluntary. The letter contained the following information:

- a brief description of the nature of the study;
- a description of what participation will involve, in terms of activities and duration;
- the guarantee that all responses will remain confidential and anonymous;
- the researcher's name, plus information about how the researcher can be contacted;
- an offer to provide detailed information about the study (e.g. summary of findings) upon completion; and
- A place for the participants to sign and date the letter, indicating agreement to participate.

With regard to permission to conduct this research involving grade 12 physical science learners within the Empangeni Education District, the researcher contacted the relevant senior educational managers, namely, Empangeni Education District Manager (Appendix F1), Lower Umfolozi Education Circuit Manager (Appendix F2) and Richards Bay Ward of schools Manager (Appendix F3). The researcher received written permission from the Empangeni Education District Manager to conduct the research (the highest authority). There was also a provision, however, that permission should be obtained firstly from the school principals. This was also done.

**Right to privacy:** The research study respected participants' right to privacy. Questionnaires were in sealed envelopes to each participant and were returned in the same way by individual respondents. Sharing information about a

respondent with others for purposes other than research is unethical, thus, information provided by respondents was kept anonymous. It is unethical to identify an individual respondent, so the researcher ensured that after information has been collected, its source could not be determined. Names of respondents were treated as confidential to protect them from embarrassment, or loss of self-esteem, or any psychological discomfort that may occur.

**Honesty with other professionals:** In writing the final report, the researcher reported his findings in a complete and honest fashion, without misrepresenting what the respondents had done or intentionally misleading others about the nature of his findings. There were no circumstances that compelled the researcher to fabricate data to support a particular conclusion. The researcher also gave appropriate credit where credit was due. The researcher was fully aware of the following as suggested by Kumar (2005):

- Acknowledgement of any use of another person's ideas or words to avoid plagiarism and documentary theft;
- Full acknowledgement of all material belonging to another person;
- Avoiding the thoughts appropriating the thoughts, ideas, or words of another person; and
- Paraphrased borrowed ideas in his (researcher's) own language without acknowledgement (Leedy, *et al* 2005: 101-102).

**Ethical Issues relating to the Researcher:** Bias on the part of the researcher is unethical. Bias is different from subjectivity. Subjectivity is related to one's background, training and competence in research and philosophical perspective. Bias is a deliberate attempt either to hide what one has found in one's study, or to highlight something disproportionately to its true existence. It is the bias that is unethical and not subjectivity.

The researcher had an obligation to use an appropriate methodology in conducting the study. It is unethical to use a method or procedure the researcher

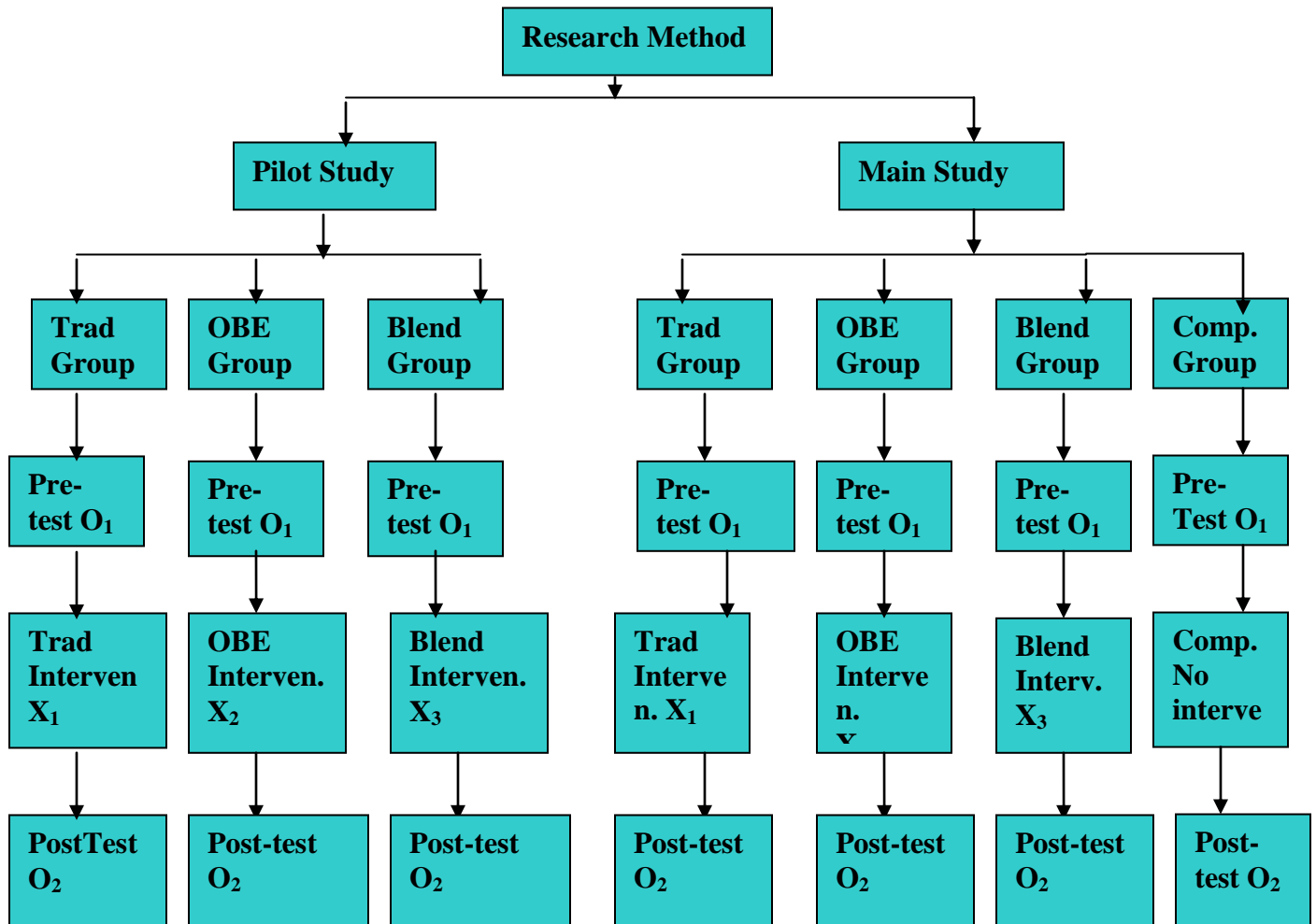


knows to be inappropriate, for example, selecting a highly biased sample, using an invalid instrument or drawing wrong conclusions. To use appropriate methodology, but to report the findings in way that changes or slants them to serve the researcher's own or someone else's interest, is unethical. The researcher desisted from being biased in any way at all the stages of the study.

### **3.14 CONCLUSION**

This chapter has presented and described the research design, target population, research sample and sampling procedures, instrumentation and the instructional interventions used in this research. Research instruments and data analysis techniques have been discussed. The next chapter focuses on the presentation and analysis of the research findings.

In Figure 3.1, The main elements of the research methods of the empirical study are summarised.



**Figure 3.1** Research Process Diagram

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 OVERVIEW

This chapter presents the major findings of this study in accordance with the research questions and hypotheses. However, before this, the biographical profile of the respondents is presented. The findings to the research questions are then presented. In this regard, firstly, the findings related to the identified most prevalent **conceptual difficulties** in mechanics amongst grade 12 physical science learners are presented and discussed. Secondly, the findings related to the identified most prevalent **alternative conceptions** in mechanics amongst grade 12 physical science learners are also presented and discussed. Thirdly, the effectiveness of the interventions developed is presented and discussed on the basis of the four hypotheses outlined in chapter 1 and 3 – and restated here as follows:

- An intervention based on the traditional instructional approach has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- An OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- A Blended instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions in mechanics.
- There is no statistically significant difference amongst OBE-based, traditional and blended instructional interventions in alleviating the conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.

The equivalence of the three groups was statistically determined and confirmed by the pre-test results.

This chapter is concluded with a discussion of the findings, which includes observations regarding the interventions, and the limiting factors of this study.

## 4.2 BIOGRAPHICAL PROFILE OF RESPONDENTS

This section presents the biographical profiles of the traditional, OBE, blended and comparison groups. The information was determined by means of a questionnaire (see Appendix A, Section A) and includes their gender, age, home and first additional language, instructional and evaluation preferences, comments on OBE and the students' familiarity with the topic under investigation. The data presented sometimes show the three distinct groups separately or collectively particularly where it had been established through the pre-test instrument that the three groups were equivalent or there was no significant difference among them.

### 4.2.1 GENDER DISTRIBUTION OF LEARNER RESPONDENTS

Table 4.1 below shows the gender distribution of the sample of physical science learners who participated in the study.

**Table 4.1**     *Gender distribution of respondents (n = 140)*

<b>Gender</b>	<b>Trad.</b>	<b>OBE</b>	<b>Blend</b>	<b>Comp.</b>	<b>TOTAL</b>
Male	12	13	11	10	56 (40%)
Female	23	22	24	25	84 (60%)
<b>TOTAL</b>	35	35	35	35	140 (100%)

Table 4.1 indicates that the research sample consisted of more girls than boys. In total there were 140 learners who participated in the study, that is, 56 males (40%) and 84 females (60%). It is interesting to see that many female learners

are interested in physical science. This female:male ratio applied to sample of this study which is a representation of the population, that is, Empangeni Education District.

#### 4.2.2 AGE DISTRIBUTION OF LEARNER RESPONDENTS

Table 4.2 below shows the age distribution of physical science learners who participated in the study.

**Table 4.2     *Age Distribution of Respondents (n = 140)***

<b>Age</b>	<b>Trad.</b>	<b>OBE</b>	<b>Blend</b>	<b>Comp.</b>	<b>TOTAL</b>
16 years	2	3	3	2	10 (07%)
17 years	11	9	8	10	38 (27%)
18 years	22	23	24	23	92 (66%)
<b>TOTAL</b>	35	35	35	35	140 (100%)

Table 4.2 indicates that the majority of learners (66%) in the research sample were older than 17 years. Relatively fewer learners (07%) were 16 years of age which implied that these learners started schooling at an early age for them to have been in Grade 12 by the age of 16.

#### 4.2.3 HOME AND FIRST ADDITIONAL LANGUAGES OF LEARNER RESPONDENTS

All (140) respondents (100%) indicated that their Home Language (HL) was Isizulu and their First Additional Language (FAL) was English. The language of instruction across all subjects was also English. Therefore, the language barrier was a possible factor with regard to the comprehension and understanding of instruction and science concepts in physical science.

#### 4.2.4 PREFERENCES OF INSTRUCTIONAL STRATEGIES

Table 4.3 shows the distribution of the participants according to their preferences with regard to instructional strategies (methods of teaching).

**Table 4.3** *Instructional Strategy Preferences of respondents (n =140)*

<b>Instructional Strategy</b>	<b>Trad.</b>	<b>OBE</b>	<b>Blend</b>	<b>Comp.</b>	<b>TOTAL</b>
Lecturing (Telling Method)	03	02	02	00	07(05%)
Practical work	12	10	11	05	38 (27%)
Self-study	00	02	01	00	03 (02%)
Group work	10	11	12	10	43 (31%)
OBE	09	08	07	11	35 (25%)
Electronic learning	01	02	02	09	14 (10%)
<b>TOTAL</b>	<b>35</b>	<b>35</b>	<b>35</b>	<b>35</b>	<b>140 (100%)</b>

Table 4.3 indicates that the majority (31%) of the learners preferred learning in groups, followed by learning through practical work or practical investigations (27%). In comparison, relatively fewer learners (05%) preferred learning through lecturing or the telling method; while 10% of the learners preferred to learn through electronic media and 0,2% preferred self-study. Looking at Table 4.3, there are also notable inter-group differences and similarities. For example, for the comparison group, no learners preferred lecturing and self-study methods of teaching and learning; in the traditional group. There are few more learners preferring electronic learning in the comparison group (09) as compared to other groups, that is, in the traditional group (01), the OBE group (02) and the blended group (02). However, these inter-group differences were very small to suggest any significant differences between/among the groups at the start of the study.

#### 4.2.5 LEARNERS VIEWS ABOUT OBE

Learners were requested to give their views regarding OBE. Some learners' comments were in favour (positive comments), while others were not in favour (negative comments) about OBE. The majority of learners though, were in favour of OBE.

- Learners' comments in favour (positive comments) about OBE:

*I think OBE was the best technique because in nowadays you get that the class is full of 60 up to 68 learners so obvious the teacher won't be able to get time to make all these learners to understand but if they are in groups it is more easy to make them understand. And also in groups you can share ideas with some group members.*

*OBE is a good method of teaching because it promote co-operation between learners and it allows learners to feel free when the teacher is teaching in terms of asking the questions, giving answers etc.*

*I think OBE is better. When the educators are doing their 100% teaching students will progress.*

*I think it is good sometimes because you understand a learner better than a teacher. Learners can help one another in case they don't understand the teacher.*

*OBE is good because it promotes communication skills. It is easy for a learner to find information from other learners.*

*I think OBE is where teachers give work to the learners and then after moves around to see how much we understand what has been given.*

*I think OBE is an easy way of learning because it gives each and every learner a chance to give views in a group, and help us work as groups.*

*OBE is a system of education where teachers must form groups in classroom, to give learners a chance to discuss and the teacher check.*

*OBE is a type of learning where there is a facilitator and learners in groups. The facilitator is there for learners to ask when they are given a task and to check that the learners are doing well or they are wrong.*

*OBE is good because it helps learners to learn to co-operate with others and learn to help one another.*

*I think OBE can be the nice strategy for learners because mostly we fail because we can't communicate to each other and we can't teach one another. If the teacher leaves us with activities, may be one of us knows it he/she should teach us and in this way we shall pass.*

*OBE helps us a lot as students because we get a chance to work as groups sharing ideas and the teacher is there to assist us. OBE also gives us chances to share different ideas as a group.*

OBE has been criticised since its introduction in schools. In addition to the above learners' statements, the empirical study reveals that OBE has its problems and advantages. Steyn and Wilkinson (1998:207) state that OBE "provides teachers with a large degree of freedom to select content and methods through which they will have their students achieve outcomes of education". According to Van der Horst and McDonald (1997:14 – 16), the following are a few of many advantages of OBE:

- Learners know what is expected of them and are able to assess their own progress. This is made possible by the stated outcomes



and the assessment criteria. In doing so, learners take responsibility for their own learning. Self-assessment is an integral part of OBE;

- OBE provides the learners with greater learning support than in the past practices. Co-operative learning technique and self- and peer-assessment are only a few examples of the learner support that should be an integral part of learning;
- Permanent failure is eliminated. Learners who do not achieve the required standard are granted further opportunities to do so; and so on.

Van der Horst and McDonald (1997:16) further state that “the effectiveness of OBE depends mainly on teachers’ abilities to implement such an approach. OBE requires hard work, a lot of planning and sensitivity towards the learning process”.

- Learners’ comments not in favour (negative comments) about OBE:

*I think OBE is not good for us because if we sit in groups we always make noise and we do not do work for ourselves we always copy work from other members of the group. But it is also useful because we can help each other when we lack in our studies.*

*OBE is not good because it is still using the old method of teaching which the one is that we using, so it can not work.*

*I think OBE must be in primary schools or else be used in high schools for those who need it.*

*I think OBE must not be used at schools because when learners are sitting in groups, they do not participate, they just sit and make noise in the class so OBE is not good for that reason.*

*OBE is good but the problem is that teachers are not able to give learners good facilitation.*

*It is not that much good because we as learners need to be taught by teachers not to share our ideas only because there are many things that we don't know.*

*I think OBE is not good because it wastes time for learners but if the teacher teaches may be half of a module and aim that the learners will try to or search about the other half and come to class to discuss what they have got, that will be good.*

In addition to the above learners' statements, Van der Horst and McDonald (1997: 16 – 19) identified the following problem areas of OBE, to mention a few:

- Outcomes which define what all learners should master often indicate behaviours and values that are vaguely worded, and are often largely associated with emotions (attitudes and values). Many of these do not focus on core academic content. A sound content base is always a prerequisite for critical thinking and problem solving;
- There is a general concern about standards. If all learners are expected to achieve the same outcomes, there is a natural tendency to lower standards, as all learners do not have the same potential, do not work equally hard, and are not equally motivated to learn. OBE holds back the gifted, and that the slower learners retard class progress;
- OBE favours the privileged schools with extensive resources, and that it creates a wider gap between privileged communities and historically deprived communities; and so on.

With regard to the NCS within the content of the Curriculum and Assessment Policy Statement (CAPS) curriculum (for the year 2012), OBE is one of the nine principles of NCS. The NCS for physical science opines that “OBE encourages a learner-centred and activity-based approach to education” (Department of Education, 2003:2). One of the learners in favour of OBE stated that “OBE helps us a lot as students because we get a chance to work as groups sharing ideas and the teacher is there to assist us. OBE also gives us chances to share different ideas as a group”. Group work and the issue of sharing ideas in class was emphasised by learners in favour of OBE. The NCS builds its learning outcomes on the critical outcomes (Department of Education, 2003:2). The critical outcomes of the NCS require learners to be able to “work effectively with others as members of a team, group, organisation and community” (Department of Education, 2003:2). One of the main pedagogical attributes of OBE is that learning should be learner-centred, teacher to function as a facilitator. The use of group work, team work and other active learning approaches are emphasized (Imenda, 2002). According to the Department of Education (2011:3) “active and critical learning; encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths”, is one of the principles on which the NCS is based. Thus OBE, as one of the principles of NCS, does not encourage traditional teaching and learning.

In the same way, CAPS, states that the NCS aims to “produce learners that are able to work effectively with others as members of a team” (Department of Education, 2011:3). The Department (2011) further states that the NCS serves the purpose of equipping learners, irrespective of their socio-economic background, race, gender, physical ability or intellectual ability, with the knowledge, skills and values necessary for self-fulfilment, and meaningful participation in society as a citizen of a free country.

Therefore the NCS, within the content of CAPS prepares learners for the broader community, so that they will be able to live with other people as social beings. Within this, OBE promotes active and co-operative learning.

The learners' comments were, in a way, related to the third research question which sought to determine the most effective approach in alleviating conceptual difficulties and alternative conceptions in mechanics. The learners' comments also were related to the second hypothesis which states that "an OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics." The empirical study supports OBE in that it is learner-centred and promotes active learning and team work. Alternative conceptions are easily detected through discussions, thereby providing an opportunity for immediate attention and correction.

#### 4.2.6 ASSESSMENT METHODS PREFERENCES

Table 4.4 shows the distribution of physical science learners according to their preferences of assessment methods.

**Table 4.4     *Assessment Method Preferences of Respondents (n = 140)***

<b>Assessment Methods</b>	<b>Trad.</b>	<b>OBE</b>	<b>Blend</b>	<b>Comp.</b>	<b>TOTAL</b>
Continuous Assessment (CA)	20	16	13	17	66 (47%)
Tests and Examinations (T & E)	00	02	01	00	03 (02%)
Both CA and T & E	15	17	21	18	71 (51%)
<b>TOTAL</b>	35	35	35	35	140(100%)

Table 4.4 indicates that the majority of learners (51%) preferred the use of continuous assessment as well as tests and examinations; 47% of the learners preferred only the use of continuous assessment. Relatively fewer learners (0,2%) preferred only tests and examinations. The traditional and comparison groups had no learners who preferred test and examinations. The blended group had the highest number of learners (21) who preferred both Continuous Assessment (CA) and test and examinations as methods of assessment, compared to the traditional, OBE and comparison groups.

#### 4.2.7 FAMILIAR TOPICS IN MECHANICS

Mechanics topics such as speed, velocity, acceleration, weight, mass, momentum and force sounded familiar to grade 12 learners except for projectile motion, work and energy and free falling bodies. The physical science curriculum is such that some topics are dealt with at grade 10 but at an introductory level, and then encountered again at a higher level where further detail is covered.

### 4.3 MOST PREVALENT CONCEPTUAL DIFFICULTIES

The first research objective concerned the identification of the most prevalent conceptual difficulties held by grade 12 physical science learners concerning mechanics. This section answers the first research question through content analysis. More specifically, the research objective reads as follows:

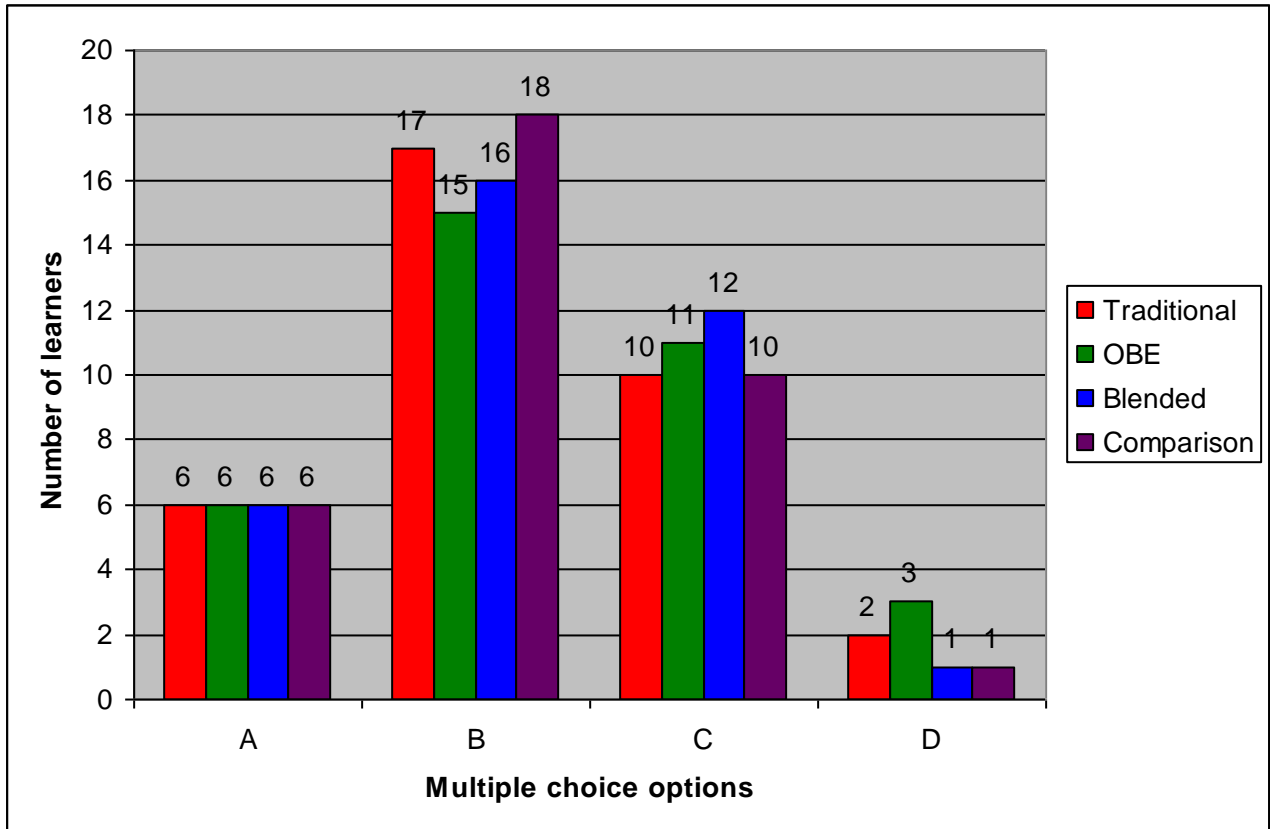
**To determine the conceptual difficulties experienced by Grade 12 physical science learners with regard to mechanics.**

#### 4.3.1 QUANTITATIVE AND QUALITATIVE ANALYSIS OF PRE-TEST

An analysis and identification of conceptual difficulties of each question in Appendix A, section B, Part I of the BMT (pre-test), questions 1 – 15 follow below. In presenting these conceptual difficulties, the learners' multiple choice question response profiles are illustrated in a figure, followed by one or more quotations from the students' motivations to further illustrate the point, as well as the number of students from a total of 140 learners who made that choice and similar motivation. A brief comment concludes the analysis of the question, which includes the model built of the students' conceptual understanding, where applicable.

Figures 4.1 to 4.15 show the graphs of the number of learners from the intervention groups (traditional, OBE and blended) who chose options A, B, C and D in the Basic Mechanics Test (BMT) pre-test. The frequencies for learners' selected options are indicated in **red** for the traditional group, **green** for the OBE group, **blue** for the blended group and **purple** for the comparison group. The conceptual difficulties identified were compared or related to what conventional science says them.

## QUESTION 1



**Figure 4.1 Number of learners who selected the intended response from the four groups**

Option C was the intended response. It is quite clear that the majority of the learners did not perform well on this question. To this effect, two different conceptual difficulties unfolded from the motivations given by the respondents, which appear to come from learners' inability to resolve the components of vectors (forces) and recognise the angle between frictional force and displacement. Friction and displacement make an angle of  $180^\circ$  with each other. This angle should be included in the formula as  $\theta$  ( $W_f = f \cdot \Delta x \cdot \cos\theta$ ). Conceptually, work is done by the component of the force that moves the object over a particular displacement or change in position. Learners tended to omit the

angle  $\theta$  in the formula  $W = F \cdot \Delta x \cdot \cos\theta$ . Thus, two conceptual difficulties were identified from this question:

**(i) Resolving components of vectors (force)**

Learners had some difficulty in using the x-component of  $F_p$  to calculate work done by  $F_p$ .  $W_p = F_p \cdot \Delta x \cdot \cos 37^\circ$

*"I failed to do calculations which were going to prove this to me".*

*"The formula I used is  $W = F \cdot \Delta x$ ."*

*"The resultant force is  $F - F_f = 100\text{ N} - 50\text{ N} = 50\text{ N}$ "*

**(ii) Recognising the angle between friction force and change in position or displacement**

Learners were unable to recognise that since friction force and change in position or displacement are in opposite directions, therefore the angle between them is  $180^\circ$  and hence work done by friction is given by,  $W_f = F_f \cdot \Delta x \cdot \cos 180^\circ$ .

*"I have no idea".*

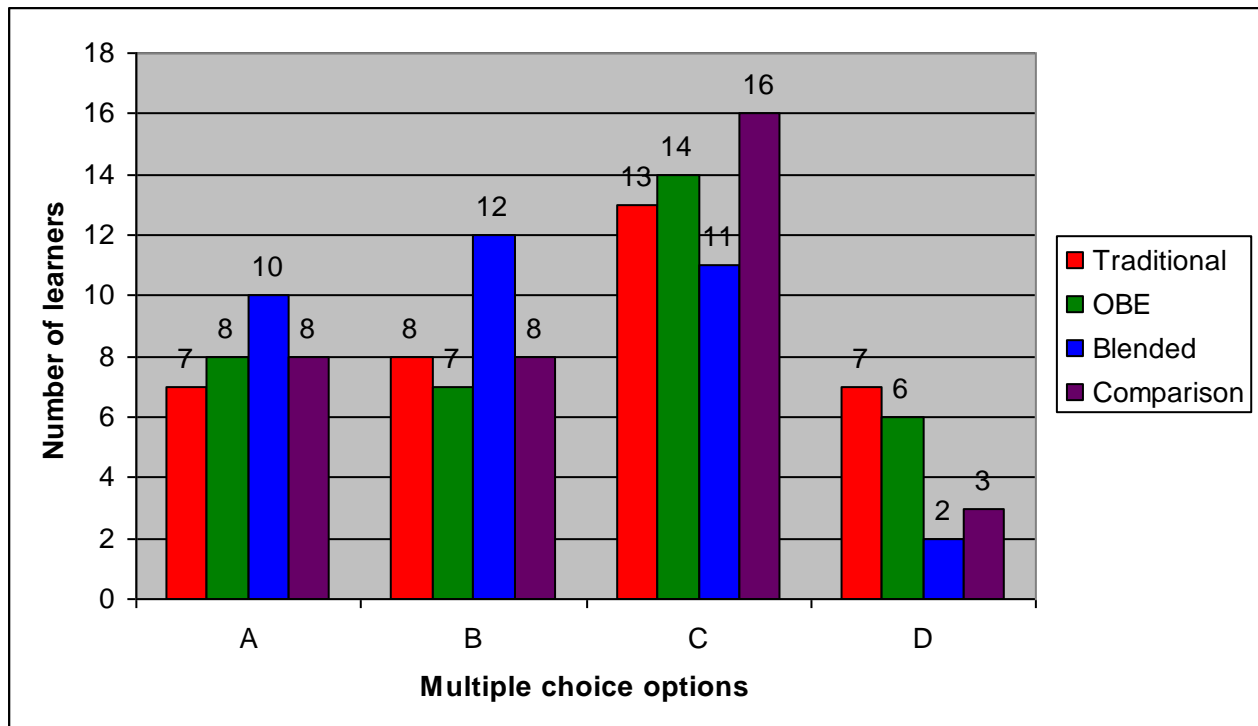
*"I did not get the idea of what was happening there".*

*"I am not confident with my choice, I am not sure".*

*"because the force applied is greater than the friction and the answer in both sides has to be positive".*



## QUESTION 2



**Figure 4.2 Number of learners who selected the intended response from the four groups**

Option B was the intended option. It is also quite clear that the majority of learners did not perform well on this question. One conceptual difficulty unfolded from the motivations given by students for their selected answers.

### **Work done by net force**

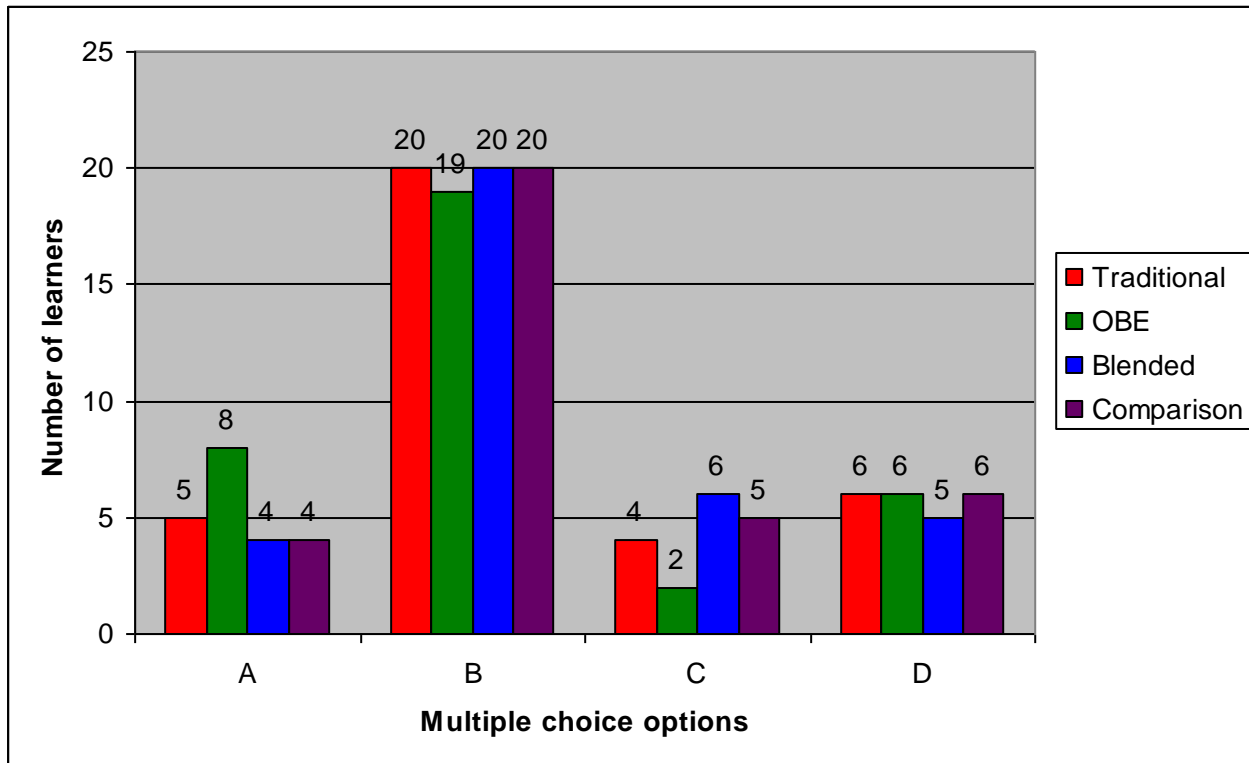
Learners could not understand the concept of work done by a **net force** and hence they considered statement III (of question 2) also as correct. Thus, the learners did not understand the work-energy theorem.

*“The statements are all true so far as I know”.*

*"I think all are true because work is done on an object when a force displaces the object in the direction of the force. Mechanical energy of a system is conserved when an external force does no work on the system. The work done on an object by a net force is equal to the kinetic energy of the object".*

This conceptual difficulty appears to emanate from statement number III of question 2 of the TBM (Appendix A), which stated that "The work done on an object by a net force is equal to the kinetic energy of the object". This statement relates to the work-energy theorem. A key phrase was omitted in statement III making it wrong, the phrase is, "change in". For this statement to be correct according to work-energy theorem, the statement should be written as follows: "The work done on an object by a net force is equal to the *change in* kinetic energy of the object". The work done is also called 'the net work' that is done on an object" since it is done by the "net force'. By way of definition, "the net force is the sum of all the forces acting on an object. Net force means "final," after the forces are added" (Tillery, 2009:29). Giancoli (2000) also define the net force as the vector sum of all forces acting on the body. The object is taken as a system in this statement and mechanical energy is a combination of the kinetic and potential energy of the object.

### QUESTION 3



**Figure 4.3 Number of learners who selected the intended response from the four groups**

Option C was the intended response, although option B was the majority option. It's quite clear that the majority of learners did not perform well on this question. Two conceptual difficulties unfolded from the learners' qualitative responses.

#### **(i) Work-energy theorem application**

Learners could not relate work done to the change in kinetic energy.

*"The total work done on an object is directly proportional to the magnitude of the speed of the object".*

## ii) Relationship between ‘work done’ and ‘velocity’

Learners thought that ‘work done’ on an object was directly proportional to the velocity of the object.

*“When the work of the car is increased the velocity of the car is also increased”.*

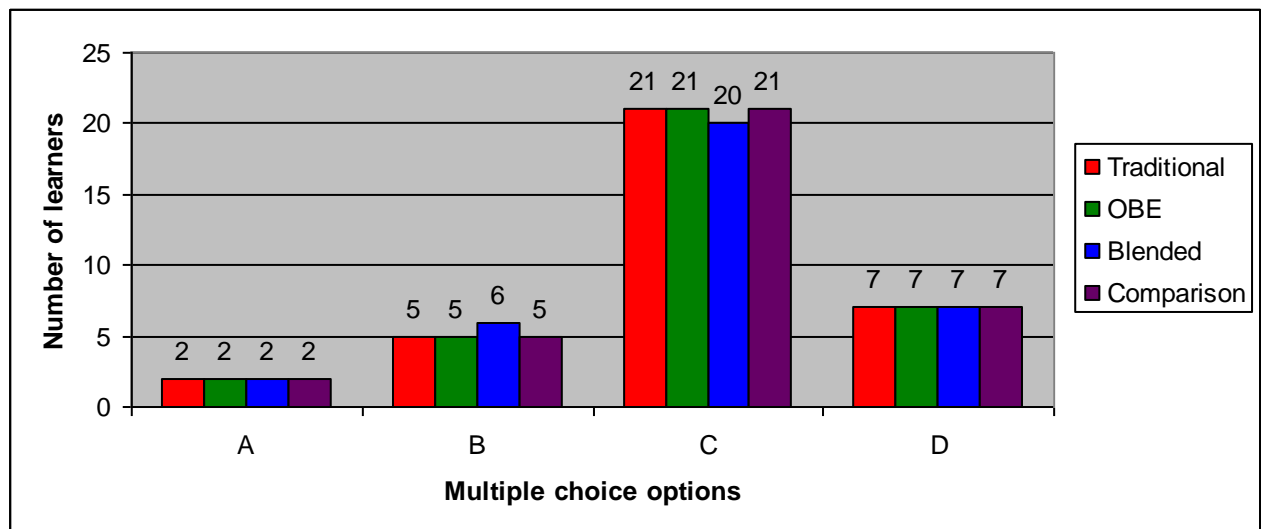
*“Work is directly proportional to the velocity”.*

*“It is directly proportional so the increase in velocity also makes the increase in work done”.*

*“According to the formula  $W = F.x$ ,  $W = Fv$ , which means the work is directly proportional to velocity”.*

Conceptual difficulties (i) and (ii) appear to emanate from the fact that when work is done energy is transferred ( $W = \frac{1}{2} mv^2$ ). Doubling the velocity increases work done four times since the velocity is squared. Therefore, the work done cannot be directly proportional to the velocity. The question was about the change in velocity and it related to the work-energy theorem. This conceptual difficulty becomes more clearly in question 4.

### QUESTION 4



**Figure 4.4 Number of learners who selected the intended response from the four groups**

Option D was the intended response. It's quite clear that the majority of learners did not perform well on this question. Two different conceptual difficulties unfolded from the qualitative responses.

### **(i) Calculation of kinetic energy and making inference**

Learners did not relate the changes in velocity to kinetic energy. They thought that if the velocity is changed from  $v$  to  $2v$ , kinetic energy also would be changed to  $2E$  (question 4).

*"When kinetic energy changes velocity also changes".*

*"When an object is moving at a constant velocity, its kinetic energy is directly proportional to the velocity and inversely proportional to the distance".*

*"Since  $E$  is directly proportional to the voltage so  $E$  is equal to 2".*

### **(ii) The effect of squaring the velocity in the kinetic energy equation, $K = \frac{1}{2}mv^2$**

Learners could not square the velocity in the kinetic energy equation and hence the majority option was C ( $2E$ ) which means that doubling the velocity of an object, the kinetic energy also doubles. This is not true for kinetic energy.

*"Velocity is directly proportional to kinetic energy".*

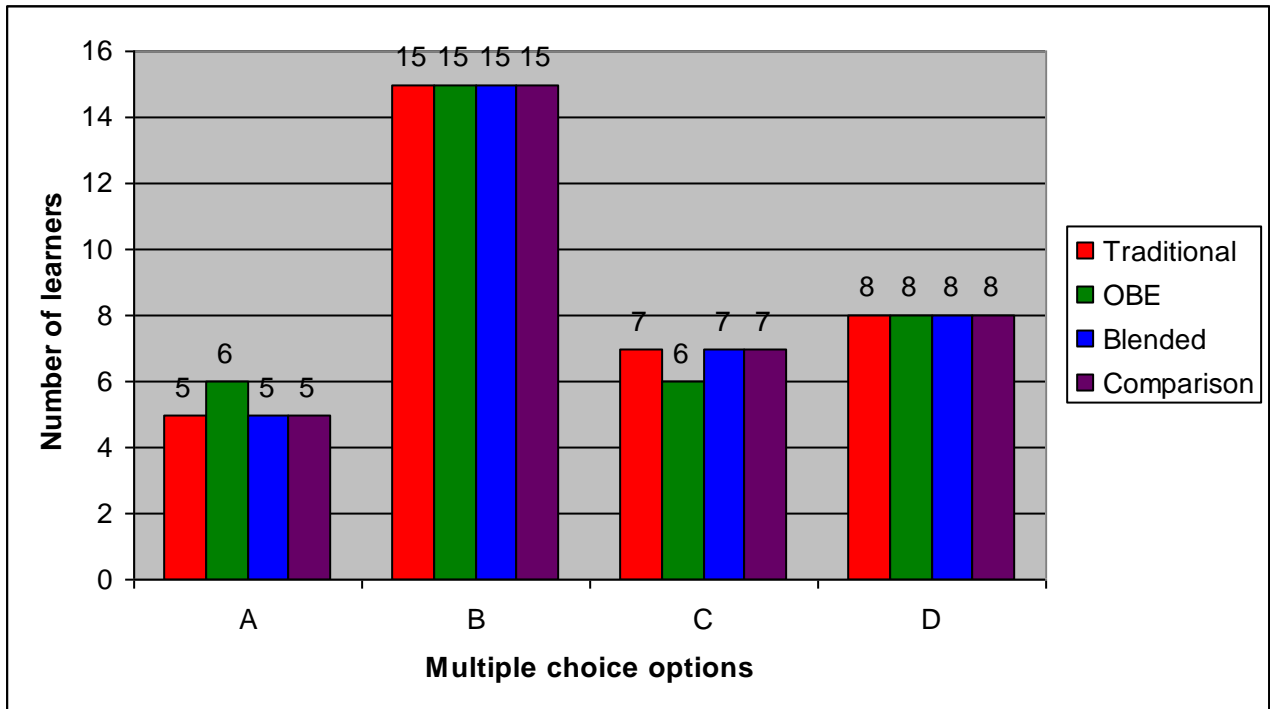
*"When kinetic energy increases, velocity also increases with the same amount".*

*"As the velocity changes to  $2v$ , so the kinetic energy will be  $2E$ ".*

The above two conceptual difficulties appear to come from the kinetic energy concept in that learners could not square the velocity in the kinetic energy

formula to solve the problem. As in question 3, by doubling the velocity, the kinetic energy becomes fourfold the previous one.

### QUESTION 5



**Figure 4.5 Number of learners who selected the intended response from the four groups**

B was the intended response option. It's quite clear that the majority of learners performed well on this question. Nonetheless, one conceptual difficulty unfolded from the qualitative responses.

**Identifying the angle between friction force (f) and change in position ( $\Delta x$ ).**

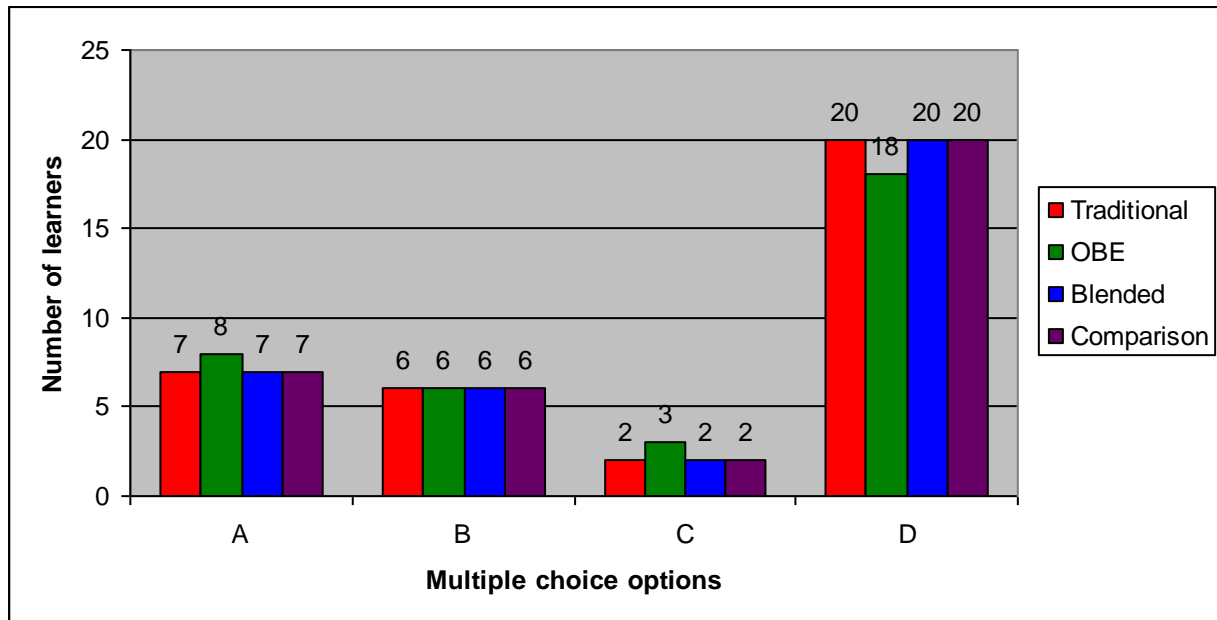
Learners thought that the angle between the friction force and the change in position was  $0^\circ$  since the angle was not shown in the diagram in question 5 and hence some learners chose both options A and C. A said that the work done by frictional force is equal to  $f \cdot \Delta x \sin 0^\circ$  and C said that the work done by frictional force is equal to  $f \cdot \Delta x \cos 0^\circ$ . This is not true. The work done by friction is expressed as  $f \cdot \Delta x \cos 180^\circ$ . It is negative work since  $\cos 180^\circ$  is equal to -1.

*“It is because on the diagram there is no angle”.*

*“A’ can be used because as shown in the figure there are no angles acting up so  $\theta = 0^\circ$ ”.*

The conceptual difficulty is the same as the one reported in question 1. Learners failed to recognise that frictional force and change in position ( $\Delta x$ ) or displacement form a straight line, thus making an angle of  $180^\circ$  with each other. Learners could not see the angle and concluded that the angle was  $0^\circ$ . Overall, the learners appeared to struggle with the concept of “work done” by friction as a concept.

## QUESTION 6



**Figure 4.6 Number of learners who selected the intended response from the four groups**

B was the intended response option, although option D came out as the majority option. It is also quite clear that the majority of learners did not perform well on this question. Two conceptual difficulties unfolded from the motivations given by the respondents.

### **(i) Identifying forces in equilibrium/balance**

Learners could not recognise that the two forces were not balancing each other since the other 200 N-force was acting at an angle  $30^\circ$  with the horizontal.

*“the forces acting on the crate are equal”.*

*“it will remain at rest because two same forces are applied in different directions”.*



*“there are two same forces acting upon so there will be no acceleration”.*

## **(ii) Finding the net force**

Learners could not calculate the net force using the x-component of force 200 N acting at  $30^\circ$  to the horizontal and the other 200 N-force acting along the x-axis.

*“The crate will be lifted up because of the angle  $30^\circ$  that is formed at the right”.*

*“The angle will influence the object to move up”.*

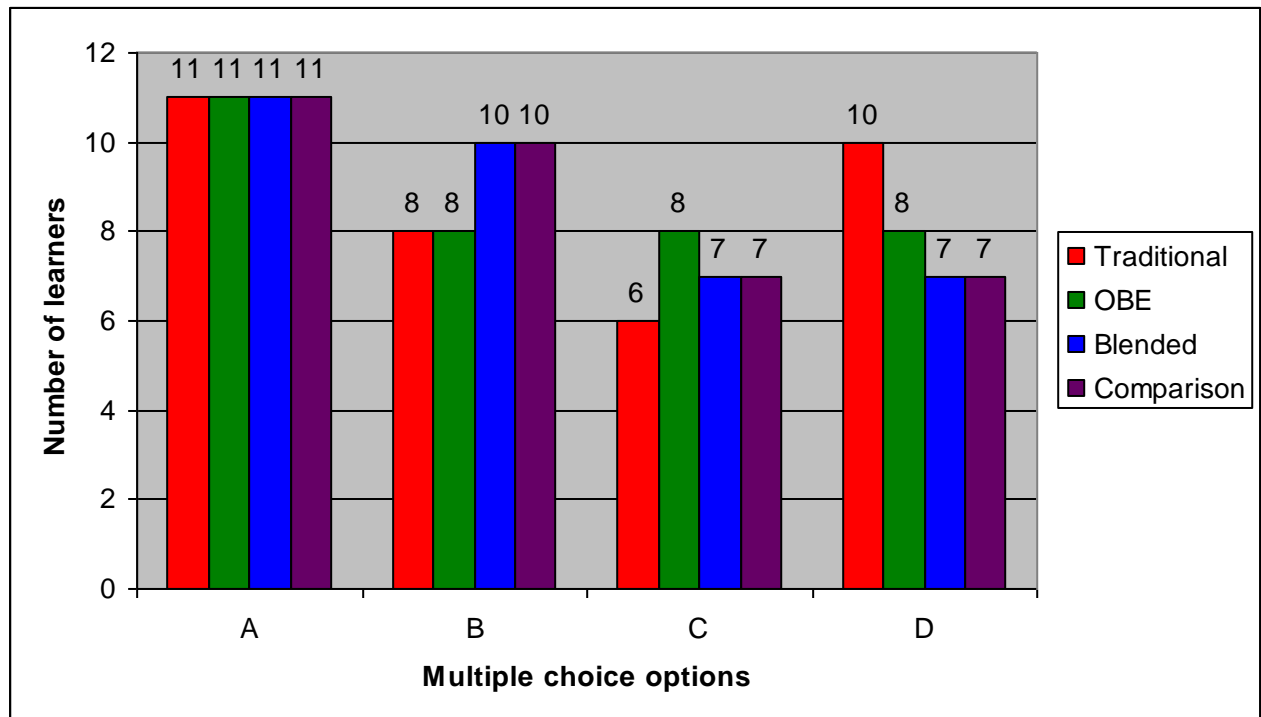
*“The crate won’t move, it will remain constant and be lifted up to the right because angles are not the same only magnitudes are same or constant”.*

*“Because the other force will pull and it will be easy for the force on the right to lift up the crate”.*

The conceptual difficulties (i) and (ii) appear to come from the fact that the forces were equal in magnitude and appeared as if they were acting in opposite directions. The issue of component resolution came in again as in question 1. Learners could not first find the horizontal component components of the force (200 N) acting at an angle  $30^\circ$  with the horizontal. Finding the component and the net force was the key in answering this question. Learners thought the forces were equal. They also confused this question with Newton’s First Law of motion, which states that an object will remain at rest or uniform motion in a straight line unless the unbalanced force acts on it.

Again, to learners, the force acting at an angle had an upward effect causing the crate to be lifted upwards and hence they thought the crate would be lifted upward.

## QUESTION 7



**Figure 4.7 Number of learners who selected the intended response from the four groups**

Option A was the intended response option. It's quite clear that many learners performed well on this question. However, the majority got it wrong. Nonetheless, one conceptual difficulty unfolded from the motivations.

### Identifying cases for no (net) work done

Learners could not see that the normal force is the force acting perpendicular to the displacement of the object (truck) and hence the normal force does no work on the truck, following the equation:

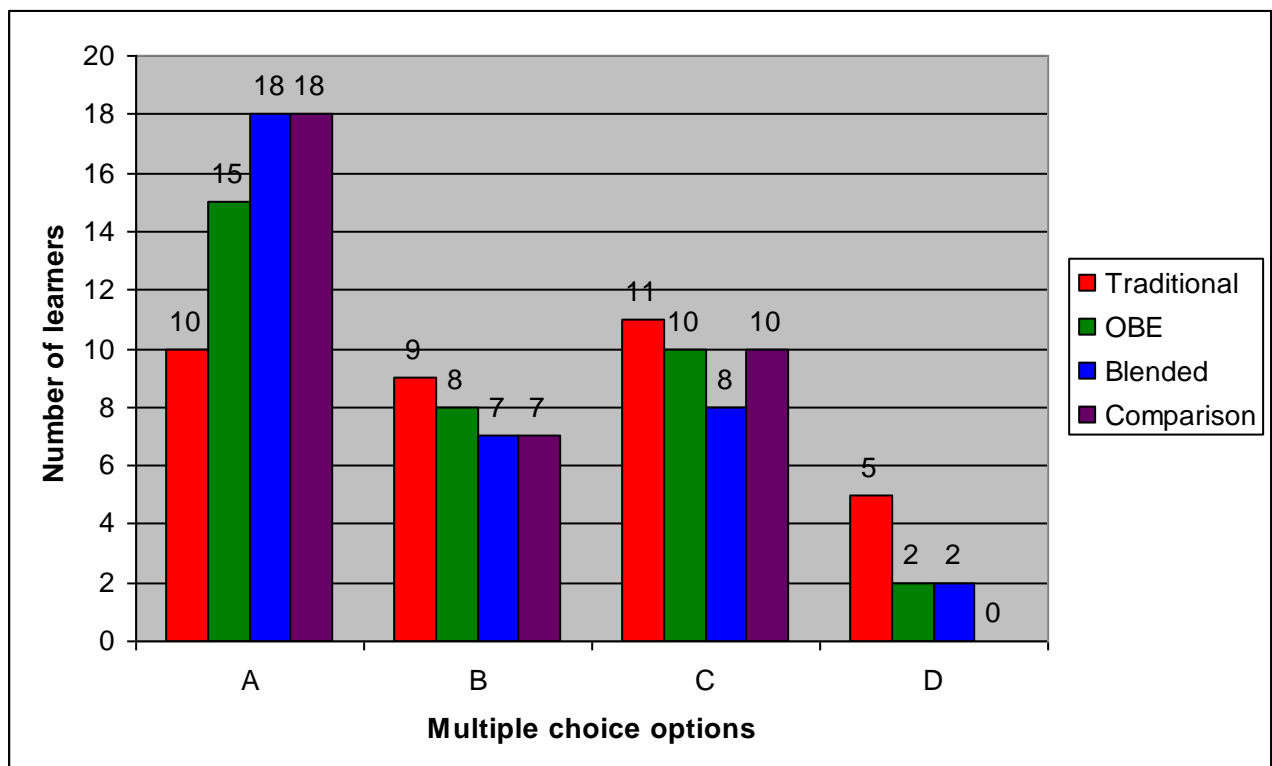
$$W = F \cdot \Delta x \cdot \cos 90^\circ, \text{ and } \cos 90^\circ = 0.$$

*“There will be no gravitational force that will take place in the slope when the truck moves from point P to point K”. As the truck slides down the inclined surface, there is work done by the gravitational force.*

*“The truck gains energy and power from the engine”.*

The conceptual difficulty appears to emanate from learners not knowing the conditions for ‘no work done’. No work is done if the force acting is perpendicular to the displacement. The force also does no work if there is no change in position or displacement of the object. In this case, the normal force was acting perpendicular to the displacement of the truck. Therefore the normal force does no work on the truck. This is confirmed by the equation  $W = F \cdot \Delta x \cdot \cos 90^\circ$ , and  $\cos 90^\circ = 0$ .

### QUESTION 8



**Figure 4.8 Number of learners who selected the intended response from the four groups**

Option A was the intended option and it was the single majority option. It's quite clear that the majority of learners could not perform well on this question. However, two conceptual difficulties unfolded from the motivations.

**(i) Resolving the components of the weight for motion on inclined plane/surface.**

Learners could not resolve the components of the weight.

*"I am lost".*

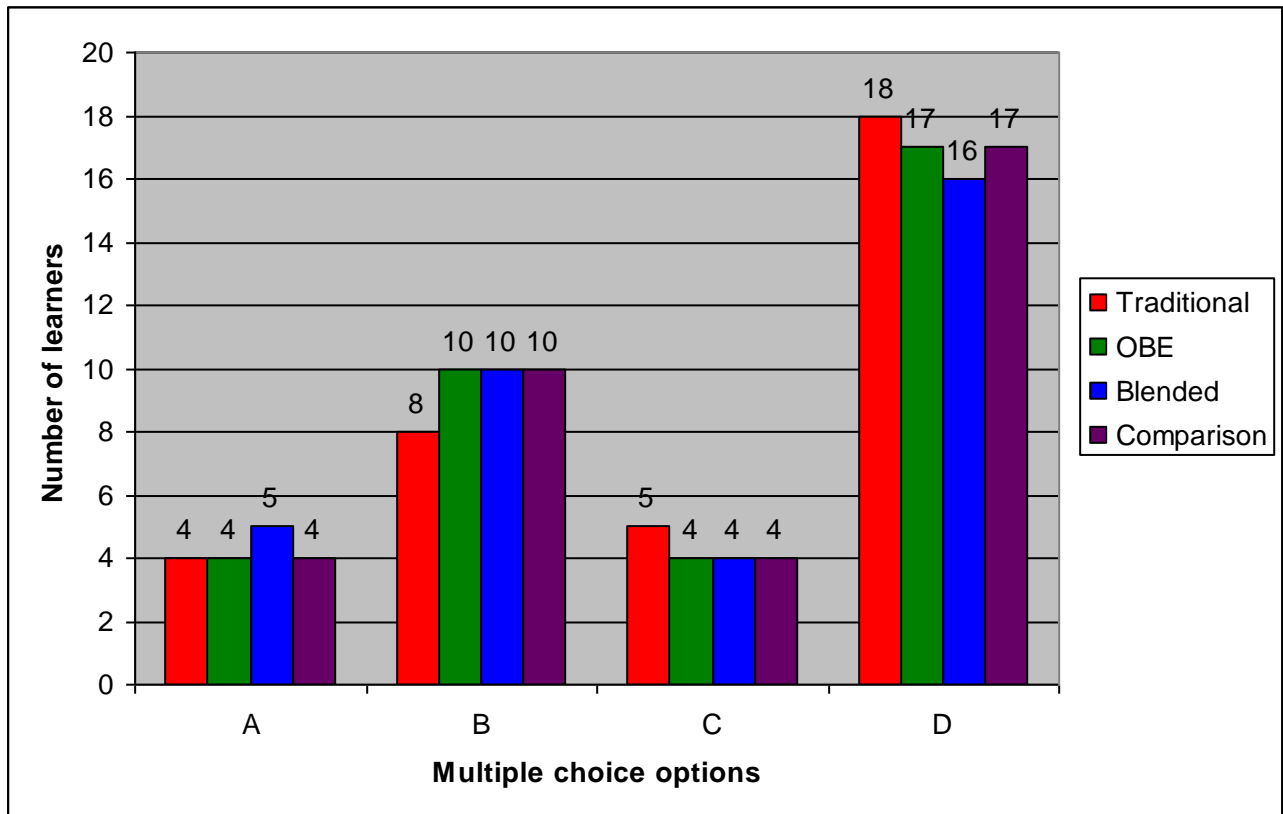
*"When we calculate the net force parallel the answer will be negative".*

**(ii) Calculating the net force**

Learners could also not calculate the net force parallel to the slope. 'Net Force' was also a difficult concept to learners.

The above two conceptual difficulties seem to emanate from the difficulty in resolving the components of the weight and the net force concept. There were 41 learners who regarded C as the intended response option. These learners did not consider the algebraic sum of linear vectors (forces), that is, components parallel to the slope and the friction force  $(207,08 + (-60) = 147,08$ ; to find the net force.

## QUESTION 9



**Figure 4.9 Number of learners who selected the intended response from the four groups**

Option D was the intended option. It's quite clear that the majority of the learners performed well on this question. Nonetheless, two different conceptual difficulties unfolded from the motivations.

### **(i) Calculating the kinetic energy**

Learners could not use proper formulas to calculate the kinetic energy of the box reaching the bottom of the slope. This was due to the lack of the concepts underlying these formulas.

*"I am lost".*

$60 \times 10 \times 2 = 1200J$ .

## (ii) Incorrect substitution

Learners could not substitute correctly as they were trying to find the correct option for question 9.

For the above two conceptual difficulties, the learners failed to identify key phrases or words in the question, for example, 'constant acceleration'. This phrase gives a clue that the equations of motion could be used in solving this problem. Some learners did choose the correct equation or formula but substituted incorrectly.

## QUESTION 10

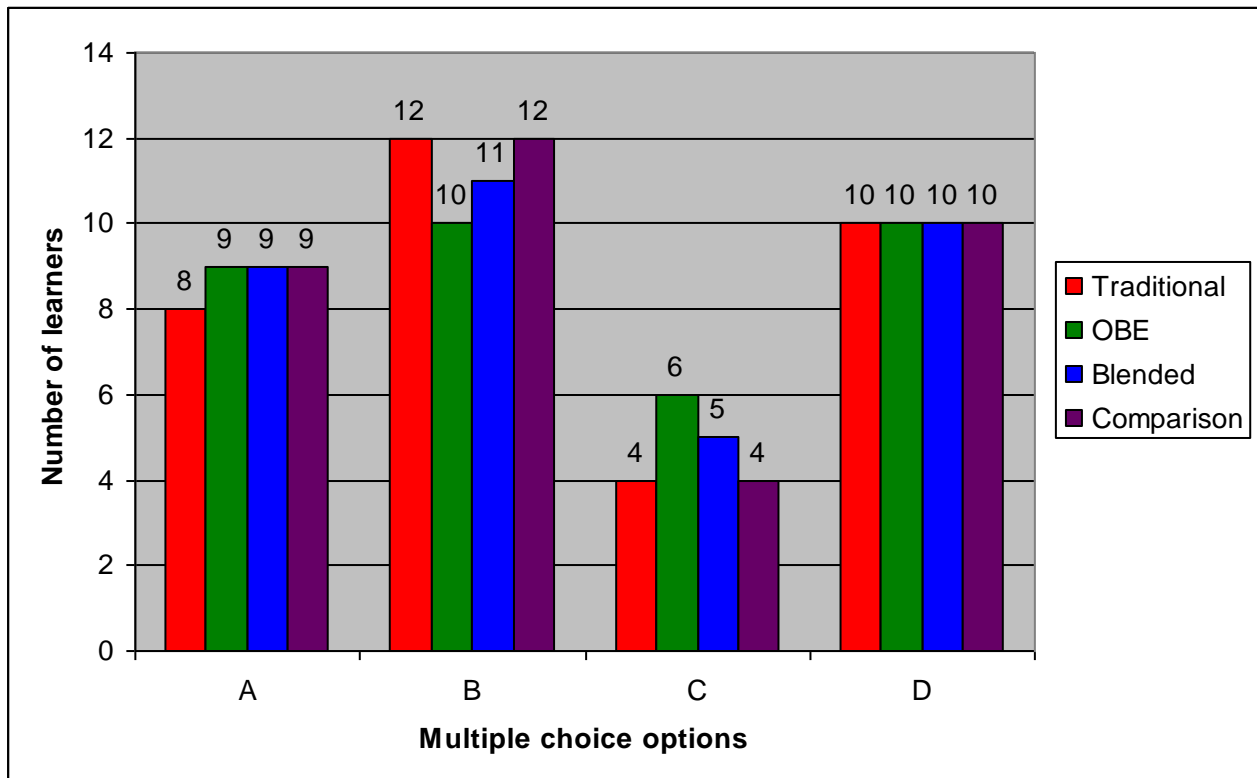


Figure 4.10 Number of learners who selected the intended response from the four groups

Option B was the intended option, as well as the single most popular response majority option. It's quite clear that the majority of learners could not perform well on this question. Nonetheless, one conceptual difficulty unfolded from the responses.

### **Finding work done by gravity for motion on inclined plane**

Learners could not calculate work done by gravitational force on the box.

*“Weight is equal to the kinetic energy”.*

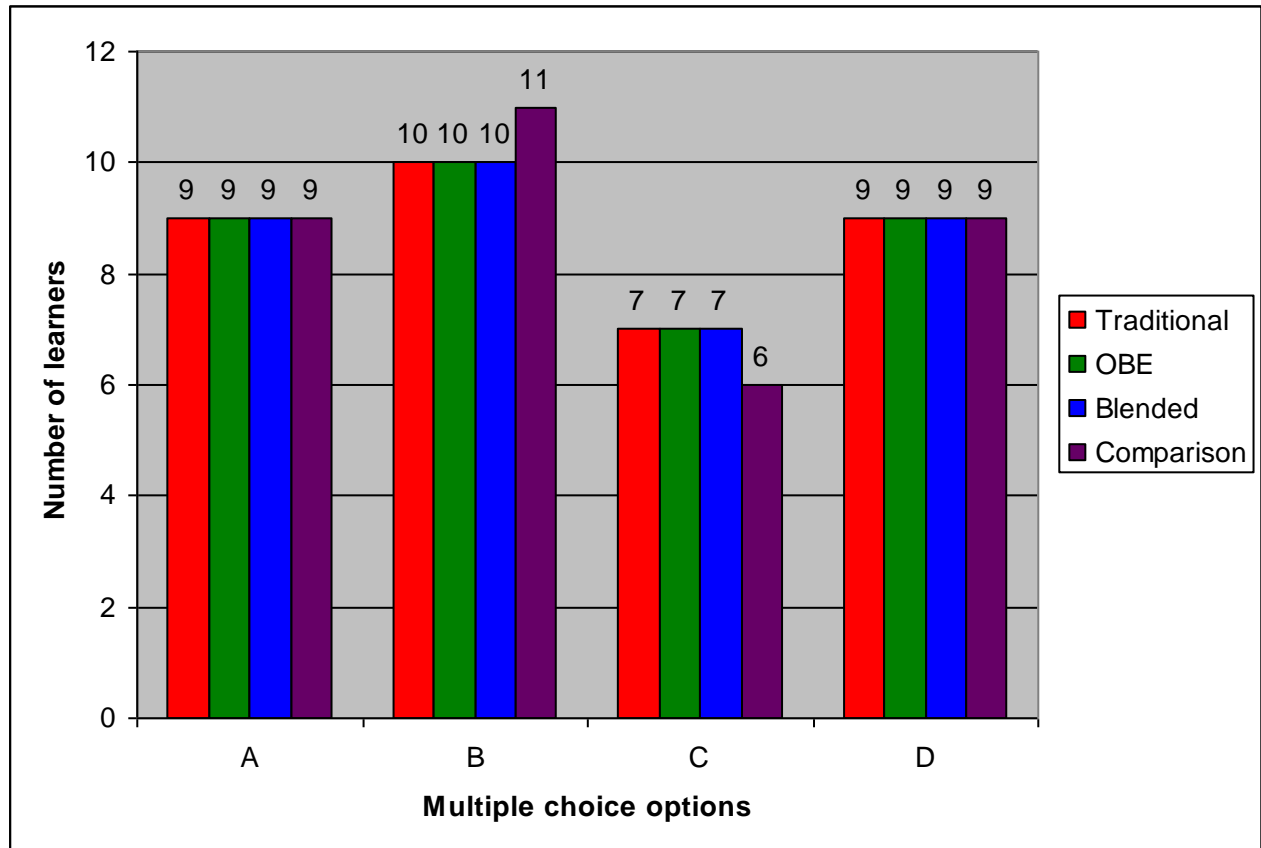
*“The gravitational force has a heavy force”.*

For the above conceptual difficulty, learners did not follow instructions. Learners who regarded option D as the correct option calculated the kinetic energy and learners who regarded C as the correct option calculated the work done by frictional force. Learners had also difficulty in resolving the components of the weight. Work done by gravity is given by the the component of the weight that is parallel to the slope and the displacement or change in position. For example,  $W_g = W_{g//} \cdot \Delta x \cdot \cos\theta$

$$\begin{aligned} &= mg \sin 25 (10) \cos 0^\circ \\ &= (60) (9.8) \sin 25 (10) (1) \\ &= 2485 \text{ J} \end{aligned}$$

Learners could not see that the angle between the component parallel to the slope and the displacement was  $\theta = 0^\circ$  since the component parallel to the slope was also parallel to the displacement and pointing in the same direction. Therefore, in that way,  $\theta = 0^\circ$  and  $\cos \theta = 1$ .

### QUESTION 11



**Figure 4.11 Number of learners who selected the intended response from the four groups**

Option C was the intended option, although option B was the most popular one followed by options A and D. It's quite clear that the majority of learners did not perform well on this question. One conceptual difficulty unfolded from the responses.

#### **Work done by friction for motion on incline planes**

Learners were not able to calculate the work done by friction.

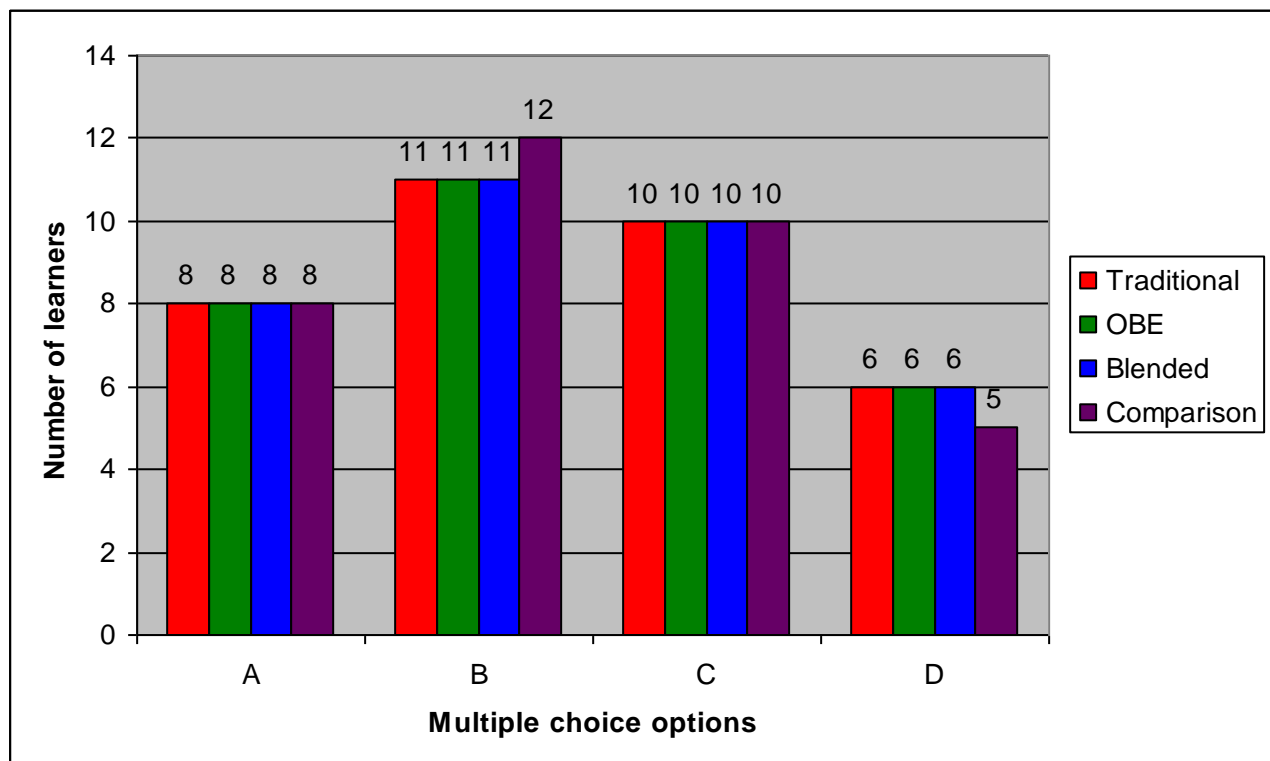
*"I do not know the formula".*



*“Very less friction was done because the slope was not rough and the potential and kinetic energy was applied”.*

For the above conceptual difficulty, learners appeared to be formula-centred in that they did not understand concepts but relied on formulas with wrong substitutions. They could not use the work-energy theorem in solving this problem. Learners lacked understanding of the attendant concepts and principles.

## QUESTION 12



**Figure 4.12 Number of learners who selected the intended response from the four groups**

Option B was the intended option. This was also the most popular single response option. It is quite clear that the majority of learners could not perform

well on this question. Nonetheless, the one conceptual difficulty which unfolded from the motivations given by the students is presented below.

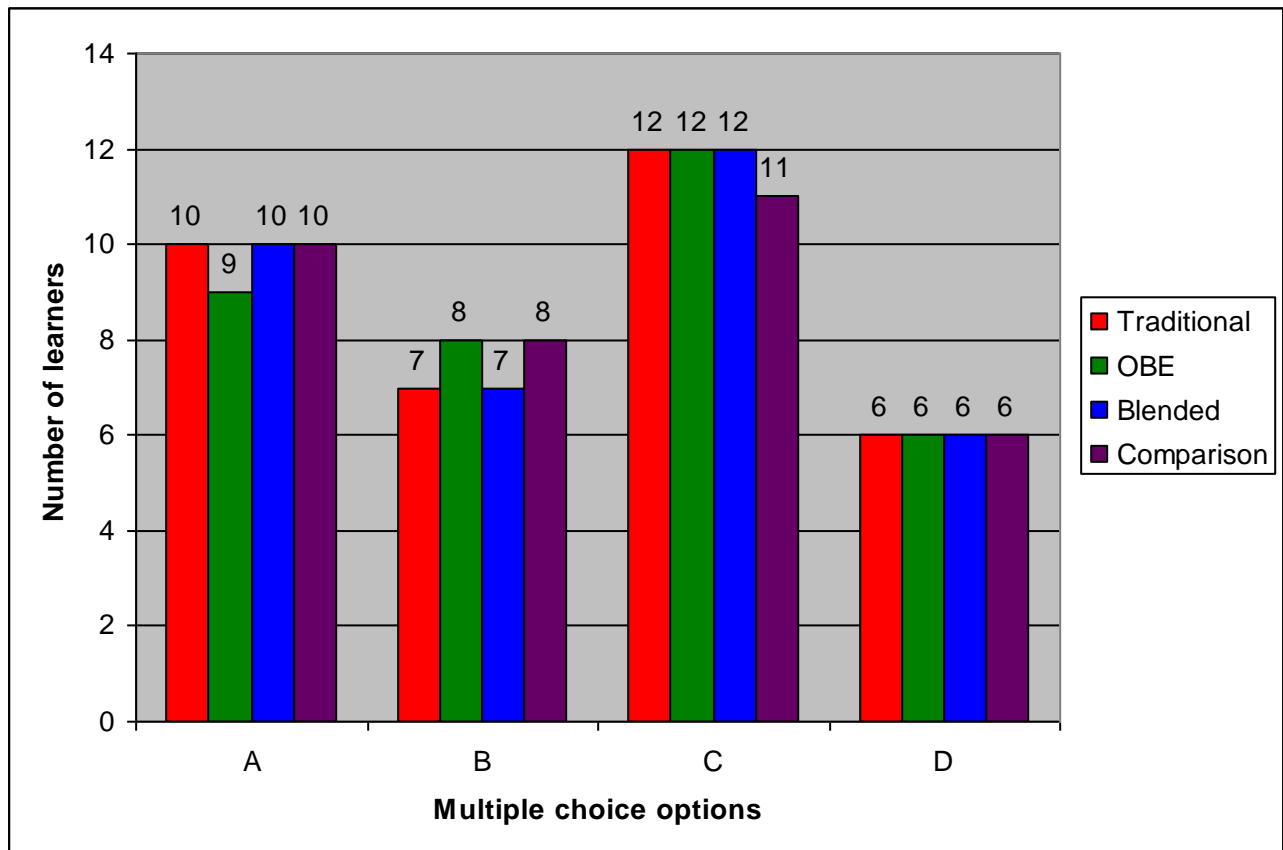
### **Magnitude as a concept**

The majority of learners could not understand the concept of ‘magnitude’ as used in science. They chose the options with negative sign representing direction. They could not understand that the word ‘magnitude’ or ‘size’ excludes direction.

*“The box has friction in order for it to move on the slope until it lands on the ground where potential energy will be zero”.*

The above conceptual difficulty seemed to emanate from the learners’ failure to understand the concept of ‘magnitude’. The question looked for the magnitude only – not the direction. Learners who regarded A as the correct option failed to understand the concept. Learners lost sight of the vector and scalar nature of the frictional force. By way of definition, a vector is a physical quantity with both magnitude and direction. The question therefore asked for the magnitude (size) only. Other options were having negative signs. Conventionally, a negative sign for vectors indicate direction.

### QUESTION 13



**Figure 4.13 Number of learners who selected the intended response from the four groups**

Option B was the intended option, although option C was the single most popular option, followed by option A. It's quite clear that the majority of learners did not perform well on this question. One conceptual difficulty which unfolded from the motivations is presented below.

#### **Application of the Principle of Conservation of Mechanical Energy.**

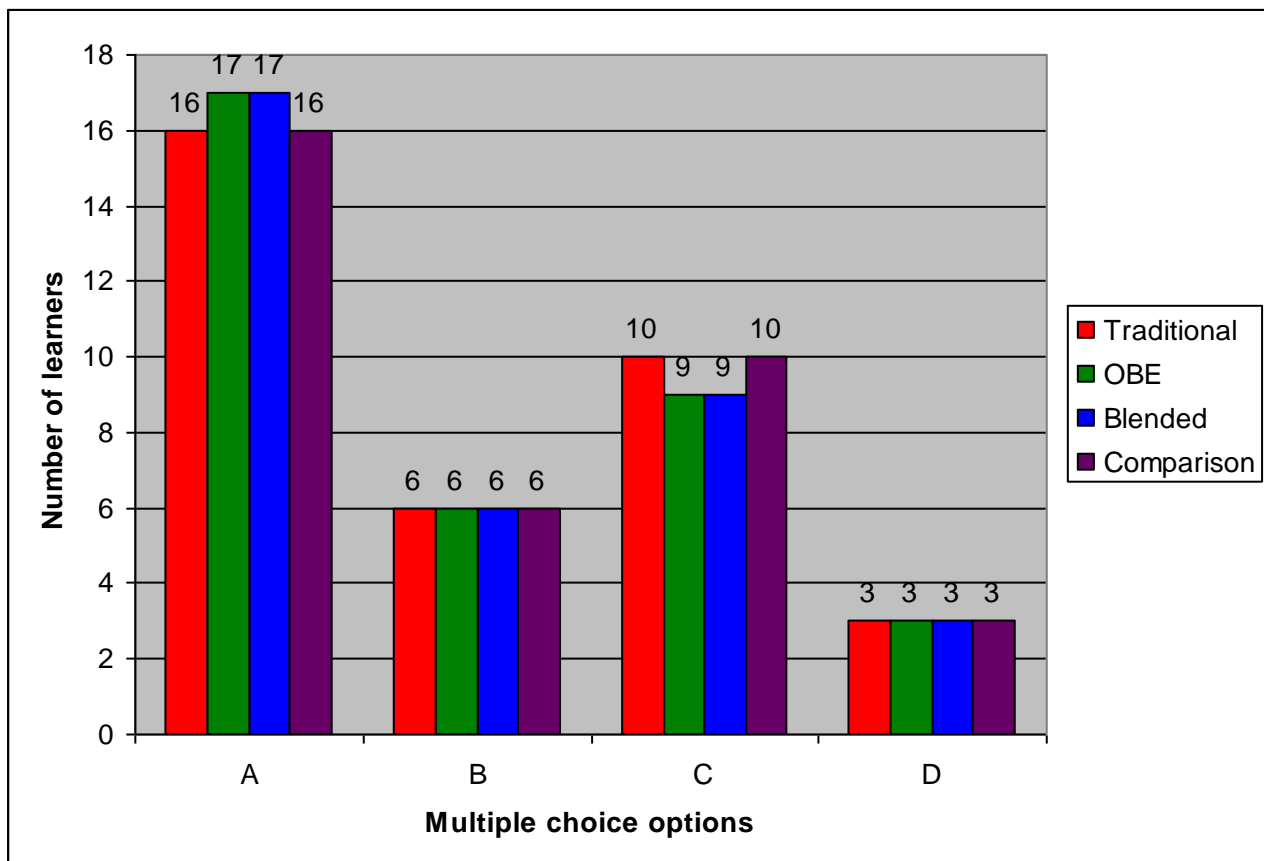
Learners could not identify key words like 'she experiences a frictional force of 18 N', and hence the majority of learners applied the Principle of Conservation of Mechanical energy which made them to make wrong choices.

*“the law of conservation of mechanical energy was applied”*

*“I am not quite sure of my answer”.*

Learners did not appear to understand the Principle of Conservation of Mechanical Energy. Learners lost sight of the fact that mechanical energy is only conserved if there are no external forces or non-conservative forces, like frictional force. Again, learners here were unable to identify key words, for example, ‘she experiences frictional force’. The Principle is about a closed system and this excludes external forces.

#### QUESTION 14



**Figure 4.14** Number of learners who selected the intended response from the four groups

Option A was the intended option. This was the majority option as well. It's quite clear that the majority of learners perform well on this question. Nonetheless, one conceptual difficulty unfolded from the learner motivations.

### Calculation of kinetic energy and correct substitution

Learners could not calculate kinetic energy and could not use proper substitution here as well.

*"I calculated the kinetic energy using the formula; I then found that at point B is going to be 2750 J which means that point A is less".*

For the above conceptual difficulty, learners could not do correct substitution into the kinetic formula  $K = \frac{1}{2} mv^2$ .

### QUESTION 15

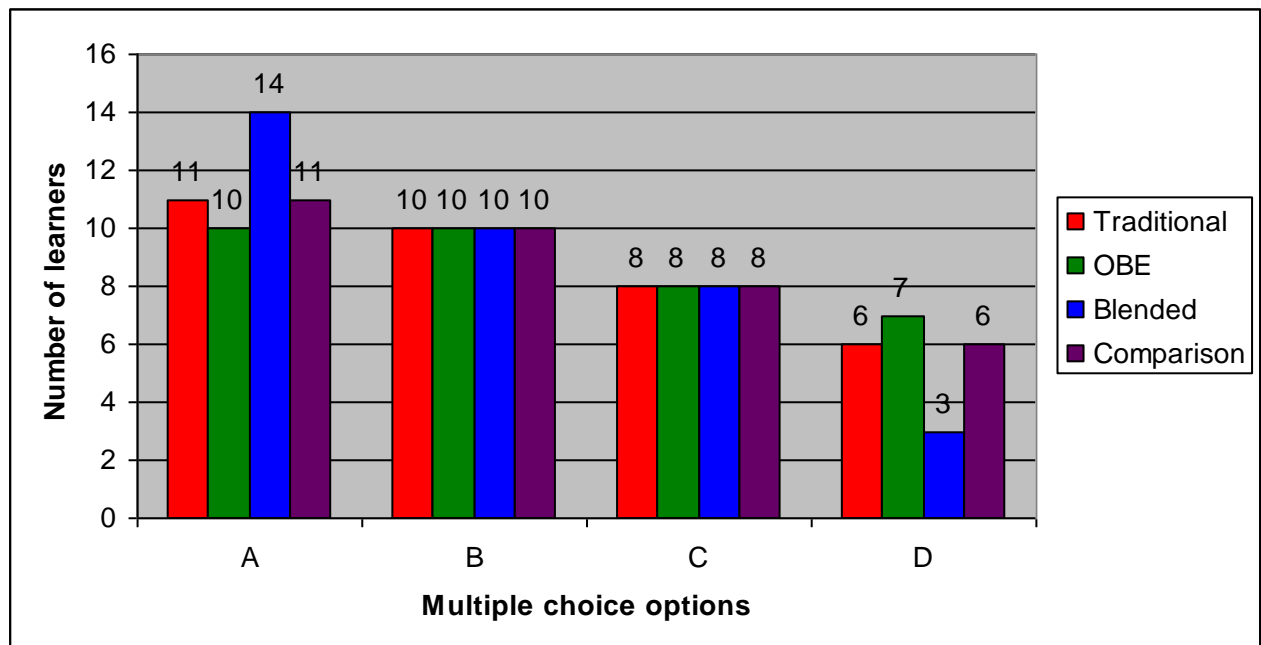


Figure 4.15 Number of learners who selected the intended response from the four groups

Option D was the intended option, although option A was the majority option followed by option B. It's quite clear that the majority of learners did not perform well on this question. One conceptual difficulty unfolded from the motivations.

### **Important variables for kinetic and potential energy**

Learners could not calculate kinetic energy for the cyclist at position B. They also could not identify variables, that is, *velocity* for kinetic energy and *height* for potential energy.

*"I have used the kinetic energy formula  $E = \frac{1}{2} mv^2 = \frac{1}{2} (55)(100)^2 = 2750 \text{ J}$ ".*

For the above conceptual difficulties, learners could not use work-energy theorem in answering this question. They also could not identify angles between the displacement and the force.

#### **4.3.2 Categories for Most Prevalent Conceptual Difficulties in Mechanics**

The conceptual difficulties, as identified from the quantitative and qualitative analysis of the pre-test questions were categorised. Table 4.5 summarises the most prevalent conceptual difficulties relating to force, work and energy concepts.

Where some conceptual difficulties appeared in more than one question, it seemed that these conceptual difficulties had a higher frequency than others. Therefore, it was not possible to add these different frequencies from different questions to indicate the order of priority of occurrence of the conceptual difficulties. From the analysis it was not possible to tell whether the same conception in one question was from the same learner or another learner in

another question. When the questions were constructed, it was not possible to foresee which conceptual difficulties would originate from a question.

Five categories of conceptual difficulties were identified. Each category was assigned a symbol (CD1 to CD5), in no specific order of significance. The frequencies for learners' conceptual difficulties are indicated in **red** for the traditional group, **green** for the OBE group, **blue** for the blended group and **purple** for the comparison group.

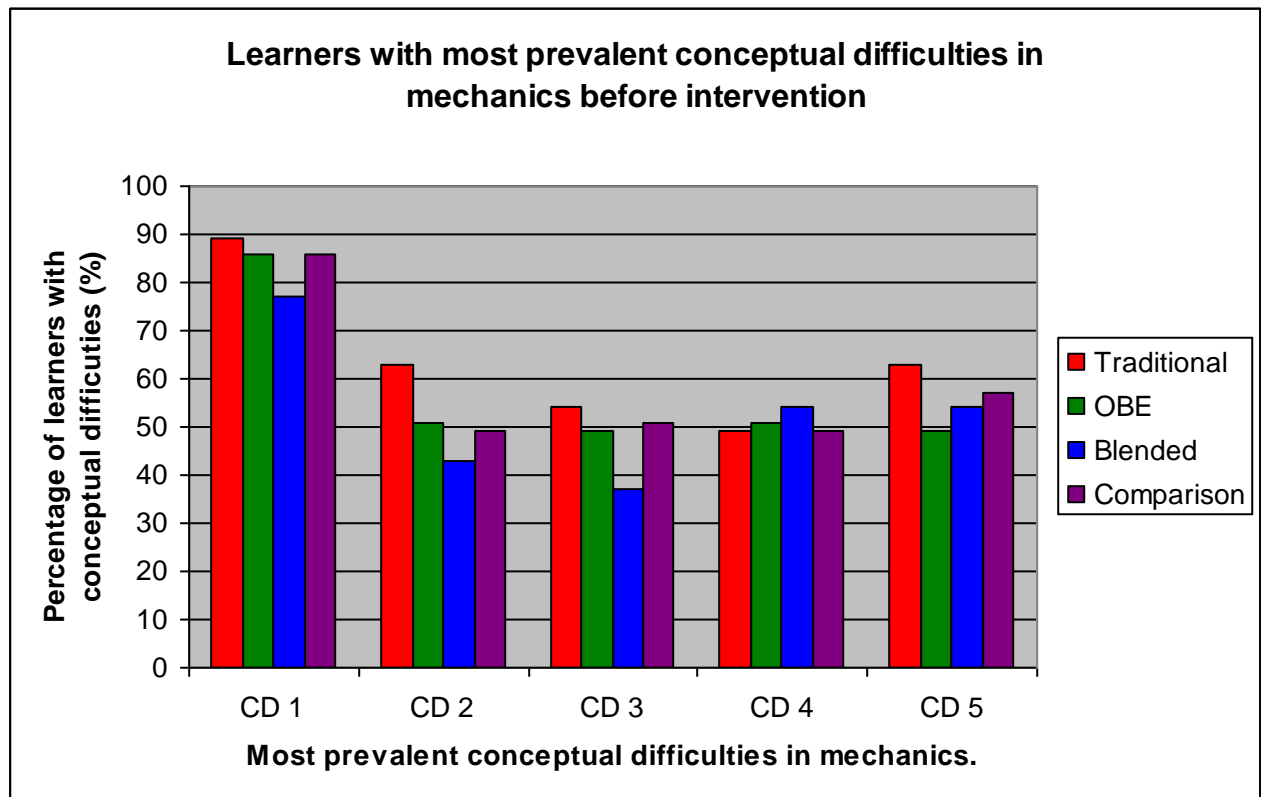
**Table 4.5: Most Prevalent Conceptual Difficulties (CD)**

Symbol	CONCEPTUAL DIFFICULTIES	Percentage of learners holding conceptual difficulties in mechanis before intervention (%)			
		Trad (35)	OBE (35)	Blend (35)	Comp (35)
CD1	<b>THEME: Resolving the Components of the weight</b> Learners encounter a challenge in solving problems that involve resolving ' <i>the components of force or weight</i> '. This is more evident when solving problems that involve motion on incline planes/surfaces.	89	86	77	86
CD2	<b>THEME: Work Concept</b> To learners, ' <i>work</i> ' is simply the product of force and displacement, that is, $W = F \cdot \Delta x$ . The issue of ' <i>the component of the force</i> ' is disregarded by learners. Thus, they cannot distinguish between ' <i>positive work</i> ' and ' <i>negative work</i> ' as well as ' <i>no work done</i> '.	63	51	43	49
CD3	<b>THEME: Work-Energy Theorem (Application)</b> Learners fairly understand work-energy theorem. This is evident when they are	54	49	37	51

	required to apply the theorem.				
CD4	<b>THEME: Kinetic Energy</b> In the kinetic energy formula, $K = \frac{1}{2} mv^2$ , learners are unable to recognize the relationship between mass and kinetic energy, and between velocity and kinetic energy.	49	51	54	49
CD5	<b>THEME: Principle of Conservation of Mechanical Energy</b> Learners fairly understand the Principle of Conservation of Mechanical Energy. This is evident when they apply the principle. Learners do not clearly understand the following concepts that relate to the principle: <i>'system', 'isolated or closed system', 'conservation', internal forces, external forces and so on.</i>	63	49	54	57

Table 4.5 indicates the most prevalent conceptual difficulties in mechanics. These conceptual difficulties need the attention of both the teacher and learners, and formed the basis for the interventions. Figure 4.16 summarises the information in Table 4.5 to show relative standings of each group across the five categories of conceptual difficulties. The frequencies for learners' conceptual difficulties are indicated in **red** for the traditional group, **green** for the OBE group, **blue** for the blended group and **purple** for the comparison group. The frequencies are indicated as percentages.





**Figure 4.16 Most Prevalent Conceptual Difficulties before Intervention**

Figure 4.16 indicates that all the four groups of learners experienced difficulties with regard to mechanics concepts, particularly, the concepts relating to work and energy. The majority of learners had conceptual difficulties in solving problems involving motion on inclined planes. They had a challenge in resolving the components of the weight. Regarding CD 1, the percentage of the learners who had a challenge with resolving the components of weight was more than 70% for each group. With regard to CD 2 to CD 5, the percentage for each conceptual difficulty, in each group was more than 40%, except for the blended group in CD 3, which was below 40%.

Thus, this summary of conceptual difficulties serves as an answer to the first research objective which sought “to determine the conceptual difficulties experienced by Grade 12 physical science learners with regard to mechanics.”

#### **4.3.2.1 CD1: Motion on Incline Planes and Components of Vectors**

THEME: Resolving the Components of the weight

Learners encounter a challenge in solving problems that involve resolving ‘*the components of force or weight*’. This is more evident when solving problems that involve motion on incline planes/surfaces. Questions 8, 9, 10 and 11 of the BTM (Appendix A) were dealing with the motion on the inclined surfaces. These questions were based on conceptual understanding and problem solving skills. To find the components of the weight, learners were firstly required to choose the coordinate system, that is, x-axis and y-axis. Secondly, to find the components, learners were required to construct a closed right-angled triangle whose sides are composed of the two coordinate system and weight vector acting as hypotenuse side. Conceptually, the components are found by using the ratio of the sides of a triangle in terms of the angle of the inclination, the weight and the other two sides of a triangle. Finally, the two components of the weight  $W$  come out as, component perpendicular to the surface,  $W_p = W\cos\theta$  and components parallel to the surface,  $W_{//} = W\sin\theta$ . Learners needed the knowledge of mathematics, that is, trigonometry, in this regard. In this connection, the Department of Education (2005) states that mathematics is a tool that is needed in physical science.

Reese (2000:199) states that learners should consider the object on the inclined plane to be the system. There are three forces acting on the object, that is, weight, normal force and friction (for rough surfaces).

For motion on a horizontal surface (non-inclined planes), any vector that is drawn at an angle  $\theta$  has two components, that is, x-component or horizontal component and y-component or vertical component. When dealing with motion on incline planes, the main issue of concern is that learners have difficulty in resolving the components of the weight. For example, the x-component and y-component of force  $F$ , that is at an angle  $\theta$  with the horizontal, can be express as  $F_x = F.\cos\theta$  and  $F_y = F.\sin\theta$ , respectively. In the same way and in many cases, the component of the weight that is parallel to the surface is expressed as  $W_{//} = W.\sin\theta = mg.\sin\theta$ . The component of the weight that is perpendicular to the surface is expressed as  $W_{\perp} = W.\cos\theta = mg.\cos\theta$ .

#### 4.3.2.2 CD2: Work Concept

THEME: Work Concept

To learners, ‘*work*’ is simply the product of force and displacement, that is,  $W = F.\Delta x$ . The issue of ‘*the component of the force*’ is disregarded by learners. Thus, they cannot distinguish between ‘*positive work*’ and ‘*negative work*’ as well as ‘*no work done*’.

The following were learners’ responses in support of their choices:

*“I am lost”.*

*“When we calculate the net force parallel the answer will be negative”.*

*“Weight is equal to the kinetic energy”.*

*“The gravitational force has a heavy force”.*

Work is defined as “the magnitude of the displacement and the component of the force acting in the direction of the displacement” (Department of Education, 2010:91). This definition can also be expressed mathematically as follows:  $W =$

$F \cdot \Delta x \cdot \cos\theta$ . The angle  $\theta$  between the force and the displacement is important. Considering this angle, it follows that the work can be categorised as *positive work*, *negative work* and *no work* depending on the size of angle  $\theta$ . For example, work is positive if angle  $\theta = 0^\circ$ , work is negative if angle  $\theta = 180^\circ$ , and no work is done on the object if angle  $\theta = 90^\circ$  (Department of Education, 2010:92). If the angle  $\theta = 0^\circ$ , it means the component of the force and the displacement are in the same direction (positive work), angle  $\theta = 180^\circ$ , means that the component of the force and the displacement are in opposite directions (negative work) and angle  $\theta = 90^\circ$ , means that the component of applied is perpendicular to the displacement and therefore there is no component of the force along the displacement (no work done). In the same vein, Cutnell and Johnson (2010:184) state that

The work done by a force is positive if the force has a component that points in the same direction as the displacement. The work is negative if there is a force component pointing opposite to the displacement... The work done by a normal force is zero, because the normal force is perpendicular to the displacement... and does not have a component along the displacement.

The component of the force also does no work if it does not produce motion.

There are therefore three conditions for no work done, that is, when there is no change in position or displacement, and when the angle between the force and the displacement is  $90^\circ$  and when there is no force exerted or applied on an object. In this connection, Bueche (1986:81) also states that “negative work is done on an object by a force that is opposite in direction to the motion of the object”. In other words, negative work is performed when the component of the force is in the opposite direction, parallel to the displacement. The angle between the friction and the displacement is  $180^\circ$  since the two vectors are opposite to each other and they form a straight line. Hence, work done by friction, or stopping force, is given by the formula  $W_f = f \cdot \Delta x \cdot \cos 180^\circ$ . But  $\cos 180^\circ = -1$  and so,  $W_f = f \cdot \Delta x \cdot (-1) = -f \Delta x$ . In this way, it can be concluded that

the work done by the friction, a stopping force, is negative (Bueche, 1986). In the same way, positive work is performed when the component of the force is in the same direction, parallel to the displacement. In this way, the angle between the force and the displacement is  $0^\circ$ . Hence, it follows that  $W = F \cdot \Delta x \cdot \cos 0^\circ$ . These are the basic concepts underpinning work as a concept.

#### **4.3.2.3 CD3: Work-Energy Theorem (Application)**

THEME: Work-Energy Theorem (Application)

Learners fairly understand work-energy theorem. This is evident when they are required to apply the theorem. The following were learners' responses in support of their choice:

Questions 2 and 3 of the TBM (Appendix A) were based on the work-energy theorem. The following were learners' responses in support of their choices to questions 2 and 3 respectively:

Qualitative responses of learners with regard to Question 2 of the TBM (Appendix A) were as follows:

*"The statements are all true so far as I know".*

*"I think all are true because work is done on an object when a force displaces the object in the direction of the force. Mechanical energy of a system is conserved when an external force does no work on the system. The work done on an object by a net force is equal to the kinetic energy of the object".*

Qualitative responses of learners with regard to Question 3 of the TBM (Appendix A) were as follows:

The work-energy theorem states that “the net work done on a system is equal to the change in kinetic energy of the system, that is,  $W_{\text{net}} = \Delta K = K_f - K_i$ ” (Department of Education, 2010:91). In the same way, Cutnell and Johnson state the work-energy theorem as follows: “When a net external force does work  $W$  on an object, the kinetic energy of the object changes from its initial value to a final value, the difference between the two values being equal to the work”. Cutnell and Johnson (2010:163) further posit that “in physics, when a net force performs work on an object, there is always a result from the effort. The result is a change in kinetic energy of the object”. Furthermore, Cutnell and Johnson (2010:163) states that “the relationship that relates work to the change in kinetic energy is known as the work-energy theorem.” In short, the work that is done by the net force produces the change in kinetic energy. By way of definition, “the net force is the sum of all the forces acting on an object. Net force means ‘final’, after the forces are added” (Giancoli, 2000:35).

The general form of the work-energy theorem is  $W = \Delta K + \Delta U$ . The work,  $W$ , done by all the other forces acting on a particle is equal to the total change in kinetic energy and change in gravitational potential energy of the particle. It must be clear that in this theorem, the net work done on the system is done by the net force. By way of definition, the net force is the sum of all forces acting on the object. Thus, the work-energy theorem is valid only if the work done is the net work done on the object (Giancoli, 2000). In the same vein, Giancoli (2000:165) states the work-energy theorem as “the net work done on an object is equal to its change in kinetic energy”. Giancoli (2000:165) further posits that

The work-energy theorem tells us that if (positive) work  $W$  is done on a body, its kinetic energy increases by an amount  $W$ . The theorem also holds true for the reverse situation: if negative work  $W$  is done on the body, the body’s kinetic energy decreases by an amount  $W$ . That is, a force exerted on a body opposite to the body’s direction of motion reduces its speed and its kinetic energy.

In this regard, it also follows that if the net work  $W$  done on an object is positive, its kinetic energy increases, whereas if the net work  $W$  done is negative, its kinetic energy decreases. In the latter case, the object does (positive) work on something else. If the net work  $W$  done on the object is zero, its kinetic energy remains constant. Putting this another way, if the velocity of the object is constant, the net work done on the object is zero since constant velocity means zero acceleration and hence zero net force according to Newton's second law of motion.

#### **4.3.2.4 CD4: Kinetic Energy**

THEME: Kinetic Energy

In the kinetic energy formula,  $K = \frac{1}{2} mv^2$ , learners are unable to recognize the relationship between mass and kinetic energy, and between velocity and kinetic energy. The following were learners' responses in support of their choices.

Learners stated that "*velocity is directly proportional to kinetic energy*". By way of definition, kinetic energy is the energy an object has as a result of its motion. Giancoli (2000) posits that kinetic energy is directly proportional to the mass of the object; it is proportional to the square of the velocity. Thus, if the mass is doubled, the kinetic energy is doubled. But if the velocity is doubled, the object has four times as much kinetic energy and is therefore capable of doing four times as much work. Kinetic energy depends on the mass and motion object. The speed is an important variable in kinetic energy. Following kinetic energy equation, Kirkpatrick and Francis (2010:117) opine that "the factor of  $\frac{1}{2}$  makes the kinetic energy compatible with the other forms of energy." They further posit that "the kinetic energy of an object increases with the square of its speed...if an object has twice the speed, it has four times the kinetic energy; if it has three times the speed, it has nine times the kinetic energy; and so on" (Kirkpatrick &

Francis, 2010:117). The relationship among kinetic energy, mass of the object and its velocity was a conceptual difficulty to learners.

#### **4.3.2.5 CD5: Principle of Conservation of Mechanical Energy**

THEME: Principle of Conservation of Mechanical Energy

Learners fairly understand the Principle of Conservation of Mechanical Energy. This is evident when they apply the principle. Learners do not clearly understand the following concepts that relate to the principle: *'system', 'isolated or closed system', 'conservation', internal forces, external forces and so on.*

*"There will be no gravitational force that will take place in the slope when the truck moves from point P to point K".*

*"The truck gains energy and power from the engine".*

*"the law of conservation of mechanical energy was applied"*

*"I am not quite sure of my answer".*

This conceptual difficulty is based on question 13 of the TBM (Appendix A) which was about the motion on a rough inclined plane whose frictional force was given as 18 N. Kirkpatrick and Francis (2010:124) state that "when frictional forces can be ignored and the other nongravitational forces do not perform any work, the mechanical energy of the system does not change." The Principle of Conservation of Mechanical Energy is therefore not conserved if there is frictional force. In this regard, Hestenes and Wells (1992:5) aver that "concerning the conservation laws for energy and momentum, it should be noted that a full understanding involves knowing when to use them in their work-energy or impulse-momentum forms".

The sum of kinetic (K) and gravitational potential energy (U) is called mechanical energy. The Law of Conservation of Energy states that energy cannot be



created or destroyed. Linked to this Law, is the Principle of Conservation of Mechanical Energy which states that the total mechanical energy ( $K + U$ ) stays the same in a closed system. Learners do not have a problem in stating the Principle in words. However, there are few terms and concepts involved in this Principle that are not clear to learners. Some of these terms and concepts includes: 'system', 'closed system', conservation, internal forces, external forces, and so on. The Department of Education (2010: 94) briefly elucidate these terms and concepts as follows:

- System: for most applications we define the object and earth as a system.
- An isolated, or closed, system is the one that has no external forces acting on it.
- Internal forces (conservative forces): these are the forces between particles or objects that constitute the system. E.g. Gravitational force, when two cars are colliding, the forces they exert during the collision are internal to the system.
- External forces (non-conservative forces): these are the forces outside the defined system. E.g tension, frictional force, air resistance.

A closed system means that only the gravitational force acts on an object and there are no other external (non-conservative) forces in as far as the Principle of Conservation of Mechanical Energy is concerned. The Department of Education (2010:86, 87) further defines a closed system as a small portion of the universe that we are interested in and we ignore the rest of the universe outside of the defined system. A system could be a single particle or object or it could be a collection of objects, for example, two cars colliding.

Giancoli (2000) states that the term 'conservation', in everyday usage means 'saving' or 'using wisely' – as when it is said that we should 'conserve energy'. In physics the word 'conservation' refers to a quantity that remains strictly constant. Thus, the Law of Conservation of Mechanical Energy can be illustrated simply as follows:  $K + U = \text{constant}$ . That is, the sum of the kinetic plus gravitational

potential energies of an object or system of objects, which is called the total mechanical energy, remains constant.

#### **4.4 MOST PREVALENT ALTERNATIVE CONCEPTIONS**

The second research objective concerned the identification of the most prevalent alternative conceptions held by grade 12 physical science learners. More specifically, the research objective reads as follows:

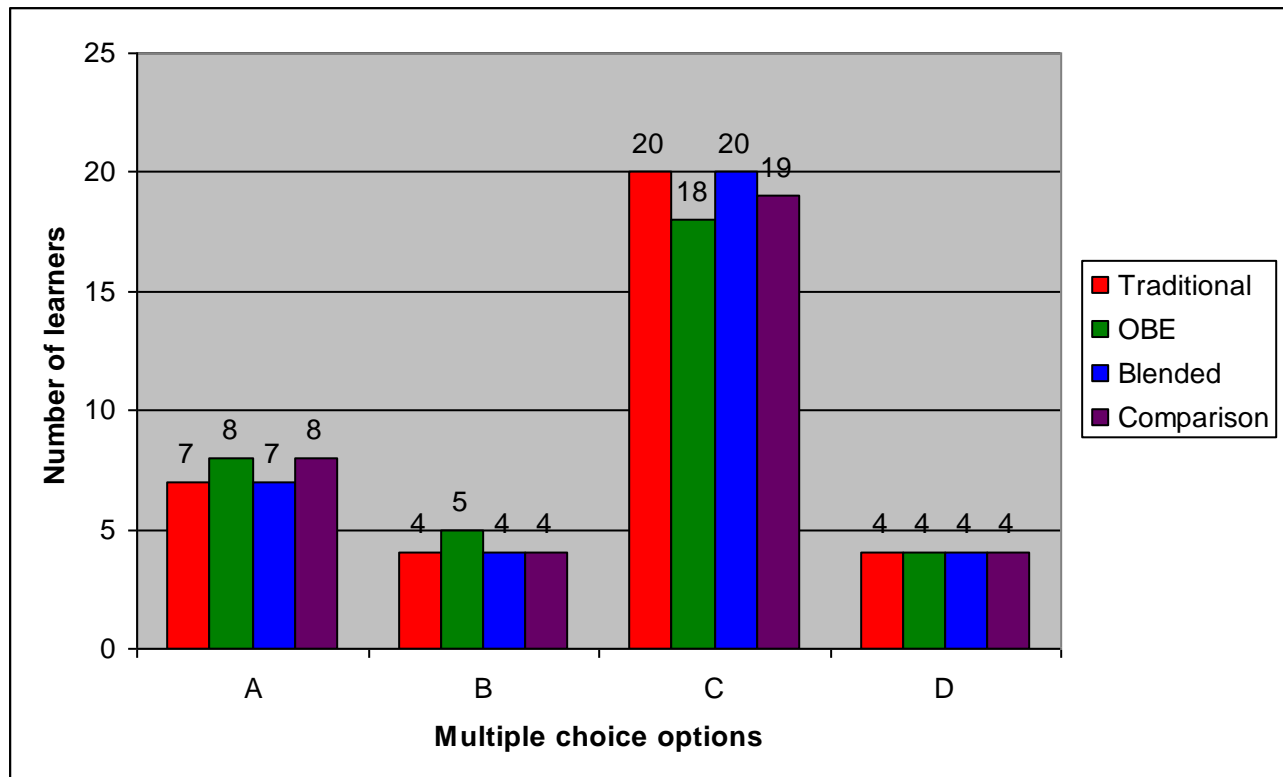
**To identify most prevalent alternative conceptions relating to mechanics amongst Grade 12 physical science learners.**

##### **4.4.1 QUANTITATIVE AND QUALITATIVE ANALYSIS OF PRE-TEST**

Steinberg, Brown and Clement, 1990:1) state that “research has shown that serious misconceptions frequently survive high school and university instruction in mechanics. A discussion of the analysis and the identification of alternative conceptions of each question in the pre-test (questions 16 – 26) follow (see Appendix A, Section B, Part II for the Pre-test and complete multiple choice questions).

Figures 4.17 to 4.26 show the graphs of the number of learners from the intervention groups (traditional, OBE and blended) who chose options A, B, C and D in the BMT. The learners’ options are indicated in **red** for the traditional group, **green** for the OBE group, **blue** for the blended group and **purple** for the comparison group. The alternative conceptions identified were compared or related to what conventional science say about them.

## QUESTION 16



**Figure 4.17 Number of learners who selected the intended response from the four groups**

Option C was the intended option. This was also a majority option. It's quite clear that the majority of learners performed well on this question. Nonetheless, one alternative conception unfolded from the motivations.

**Position** of the stone (projectile) **increases** as it is thrown vertically upwards.

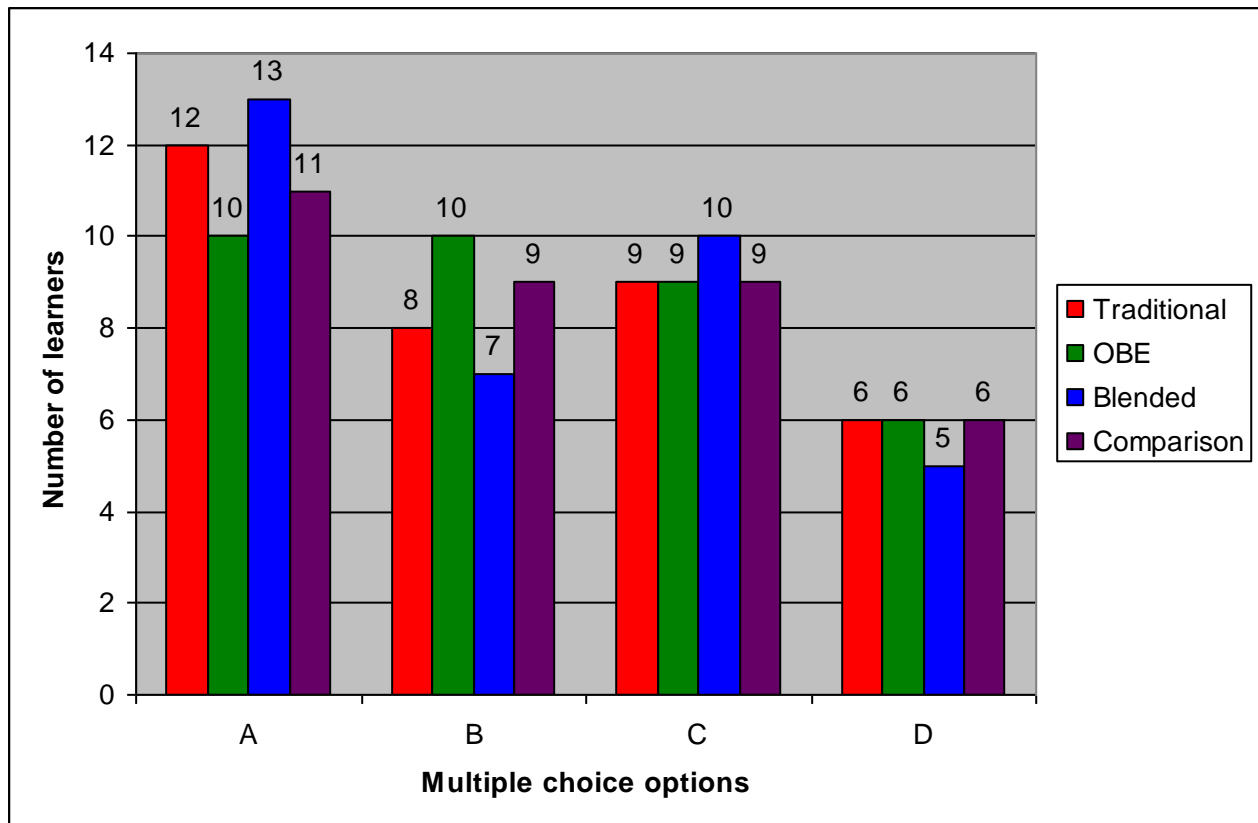
*"When the stone is thrown upward there is an increase in position and when the stone returns down the position decreases until it reaches the thrower's hand which makes the displacement zero".*

*"The position of the stone as it moves upwards and downwards it does not change".*

*“Because when you throw a stone or whatever upwards you apply a normal force”.*

The alternative conceptions appear to emanate from the inappropriate use of scientific language. For example, “position increases”, instead of saying the “position changes”. The position will not change only if the object is at rest. The position of an object that is in motion will keep on changing.

### QUESTION 17



**Figure 4.18 Number of learners who selected the intended response from the four groups**

Option C was the intended option, although option A was the majority option followed by option B. It's quite clear that the majority of learners did not perform

well on this question. Three different alternative conceptions unfolded from the responses.

(i) The **direction** of both velocity and acceleration is the **same** as the stone (projectile) goes upwards.

*“The velocity is the same when the stone goes up even when it returns back, it is conserved”.*

*“I think velocity and acceleration should be the same”.*

*Because when the stone goes up, acceleration and velocity does not change, it remains the same”.*

*“The direction of both velocity and acceleration is the same as the stone moves upwards”.*

(ii) Acceleration **increases** as the stone goes up.

*“I think acceleration increases as the stone goes up”.*

*“Increasing velocity results in increasing acceleration for upward motion”.*

*“While the stone is accelerating upwards, the velocity is increasing”.*

*“As the stone moves vertically upwards, the velocity decreases while the acceleration increases”.*

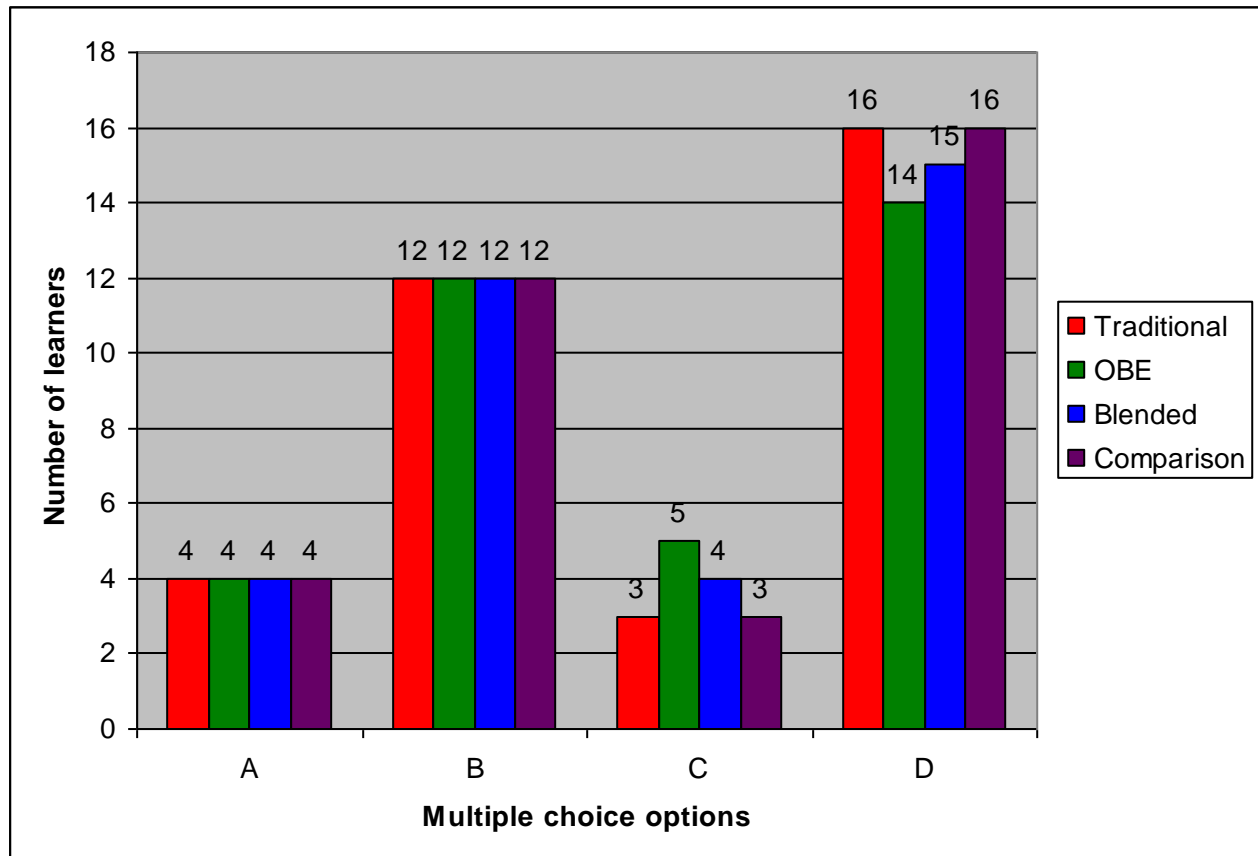
(iii) Velocity is **constant** for upward motion of the stone.

*“The time taken the stone goes up the velocity remains constant”.*

The above three alternative conception (i), (ii) and (iii) appear to come from the fact that the object that is thrown vertically upward is given an initial velocity before it leaves the thrower’s hand. Learners also do not realise that gravity is acting on the object while it is moving upwards. Again, if the velocity of the object can increase as it goes upward; this would mean that the object would

never return. Therefore, the velocity decreases as the object moves upward and the acceleration due to gravity remains constant.

### QUESTION 18



**Figure 4.19 Number of learners who selected the intended response from the four groups**

Option B was the intended option, although option D was the majority option. It is quite clear that the majority of learners did not perform well on this question. Two different alternative conceptions unfolded from the motivations.

(i) Velocity **increases** as the stone goes up

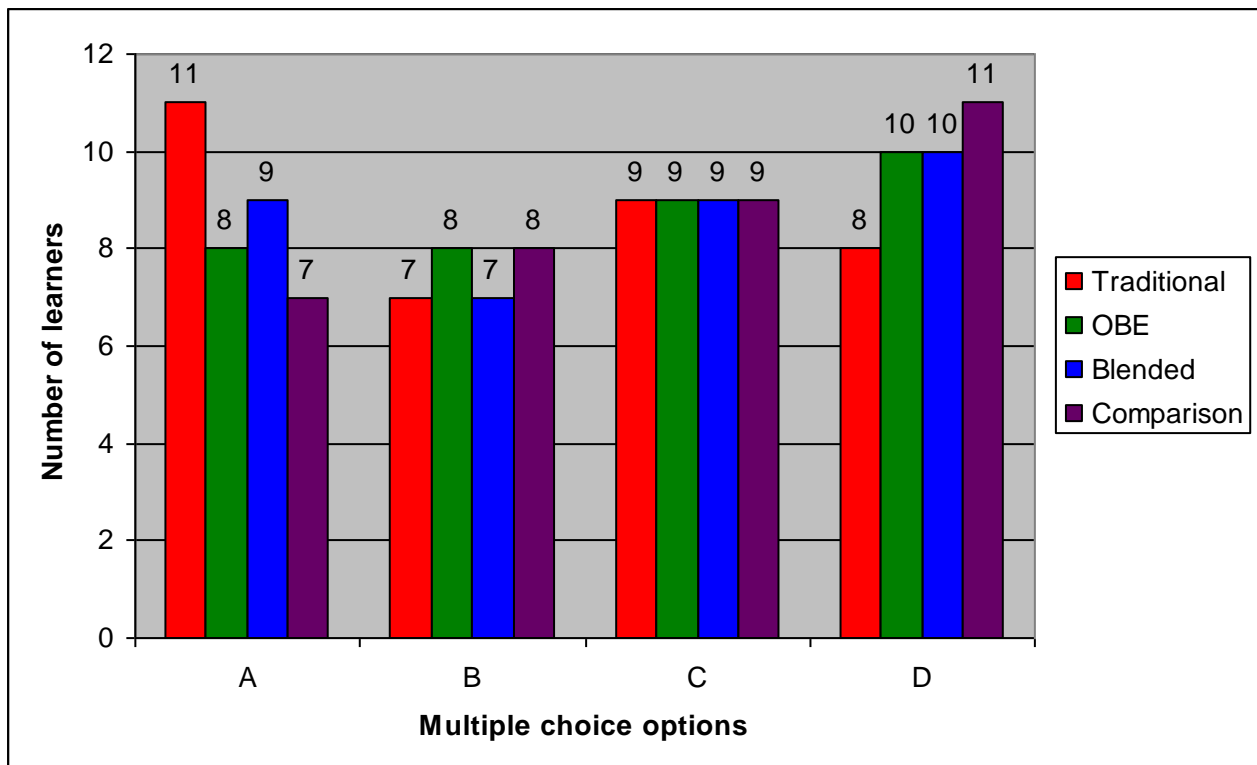
*“The velocity increases as the stone goes up”.*

(ii) Velocity and time are **directly proportional**

*“Both the time and velocity was increasing when the stone went up and returned down”.*

The above two alternative conceptions (i) and (ii) appear to emanate from the same source as discussed in the previous question. Velocity and time cannot be directly proportional for this question. In this case time is an independent variable. Time cannot increase but can be short or long. Learners lacked appropriate use of scientific language as well in answering this question.

#### QUESTION 19



**Figure 4.20 Number of learners who selected the intended response from the four groups**

Option D was the intended option. It's quite clear that the majority of learners perform well on this question. Nonetheless, two different alternative conceptions unfolded from the motivations. Here learners did not follow the instruction that required the learners to look for the incorrect statement.

(i) The **velocity** for upward motion of the ball is **same** as the **velocity** for downward motion of the ball.

*“the ball returns to Jenny’s hand with the same velocity”.*

(ii) **Acceleration** for upward motion of the ball is **same** as acceleration for downward motion **but opposite in direction**.

*“both the velocity and acceleration do not change for the whole trip of*

(iii) **Acceleration** is **zero** at the highest point.

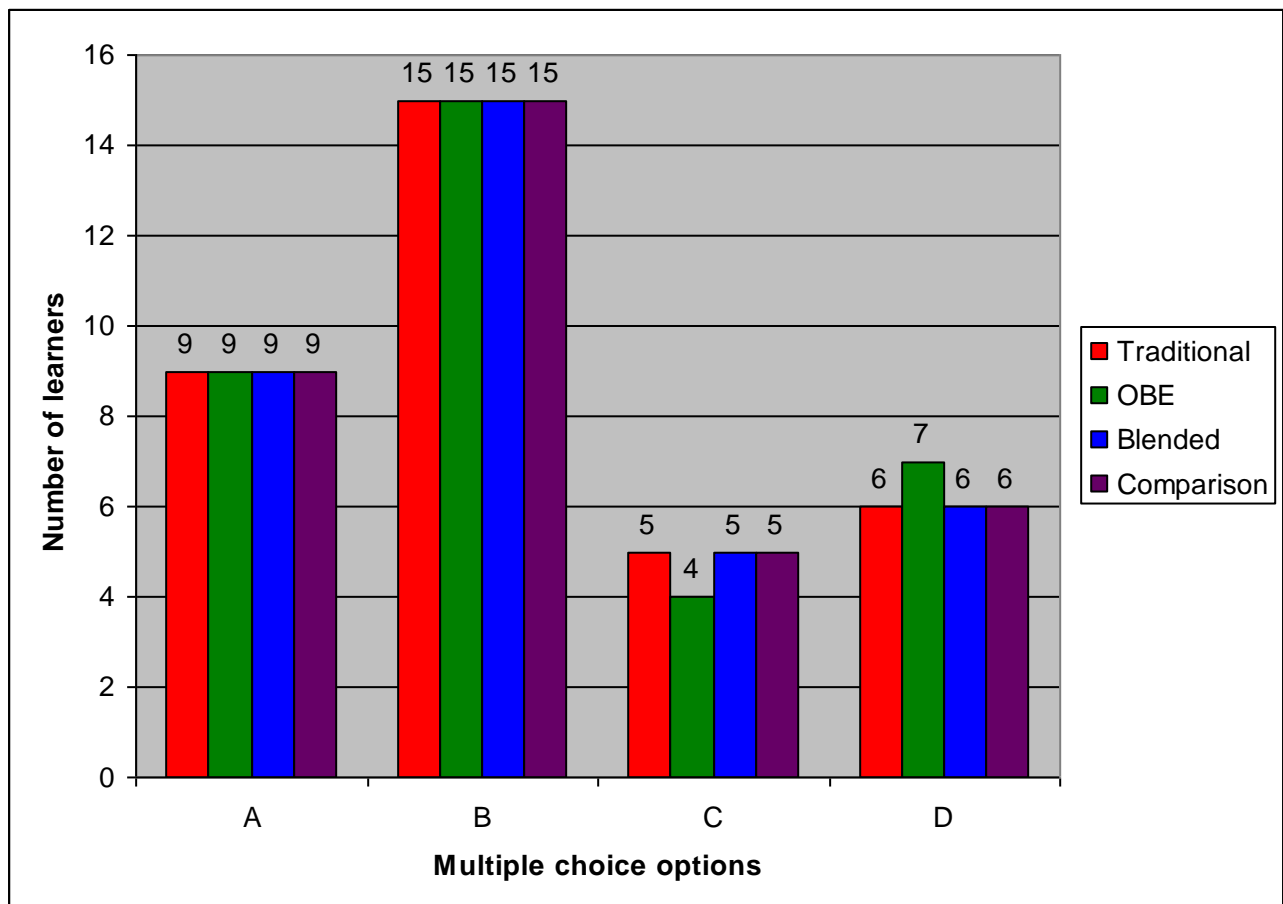
*“The acceleration of the tennis ball is zero at the highest turning point”.*

The alternative conception (i), (ii) and (iii), appears to emanate from failure to recognise that velocity is a vector quantity. Regarding alternative conception (iii), it is the velocity that is zero at the highest point and not the acceleration. Gravity is acting throughout the projectile's motion even at the highest point. Therefore, acceleration  $a = g = 9.8 \text{ m.s}^{-2}$  (downward) even at the highest point of the tennis ball's motion. Giancoli (2000:36) posit that “when the ball is moving upward, its velocity is positive (upward), whereas the acceleration is negative (downward).” For motion in two opposite directions, it is important to choose signs for directions in case of vector quantities or specify directions. The velocity of the ball as it goes upwards cannot be the same as the velocity of ball as it returns downward to Jenny's hand, but the speed can be the same for both direction (up and down) since the speed is a scalar quantity. The speed measured in  $\text{m.s}^{-1}$



changes under the influence of the acceleration due to gravity as the ball moves up and down. At the highest point the speed is zero, just before the ball returns. In the same way, the magnitude of the velocity for both directions can be the same but not velocity as such since it includes direction. Again, here as well, some of the learners could not follow the instruction. The question was looking for the incorrect statement but some of the learners gave the correct statements.

## QUESTION 20



**Figure 4.21** Number of learners who selected the intended response from the four groups

Option A was the intended option, although option B was the majority option. It's quite clear that the majority of learners did not perform well on this question. Three different alternative conceptions unfolded from the motivations.

- (i) Stone that is dropped has the **velocity greater than zero before it is dropped. Time** is also affected.

*"Because the acceleration or the speed of the ball will increase as it is dropped".*

*"The stone time will decrease as the stone is falling down".*

*"the kinetic energy is more powerful when a moving object is at rest, for a few time".*

*"kinetic energy increases as the stone is dropped from the cliff also the time increases".*

- (ii) Stone that is dropped moves with a **constant velocity**.

*"The stone's velocity is does not change as it goes vertically down."*

*"The velocity of the stone is constant when it falls down."*

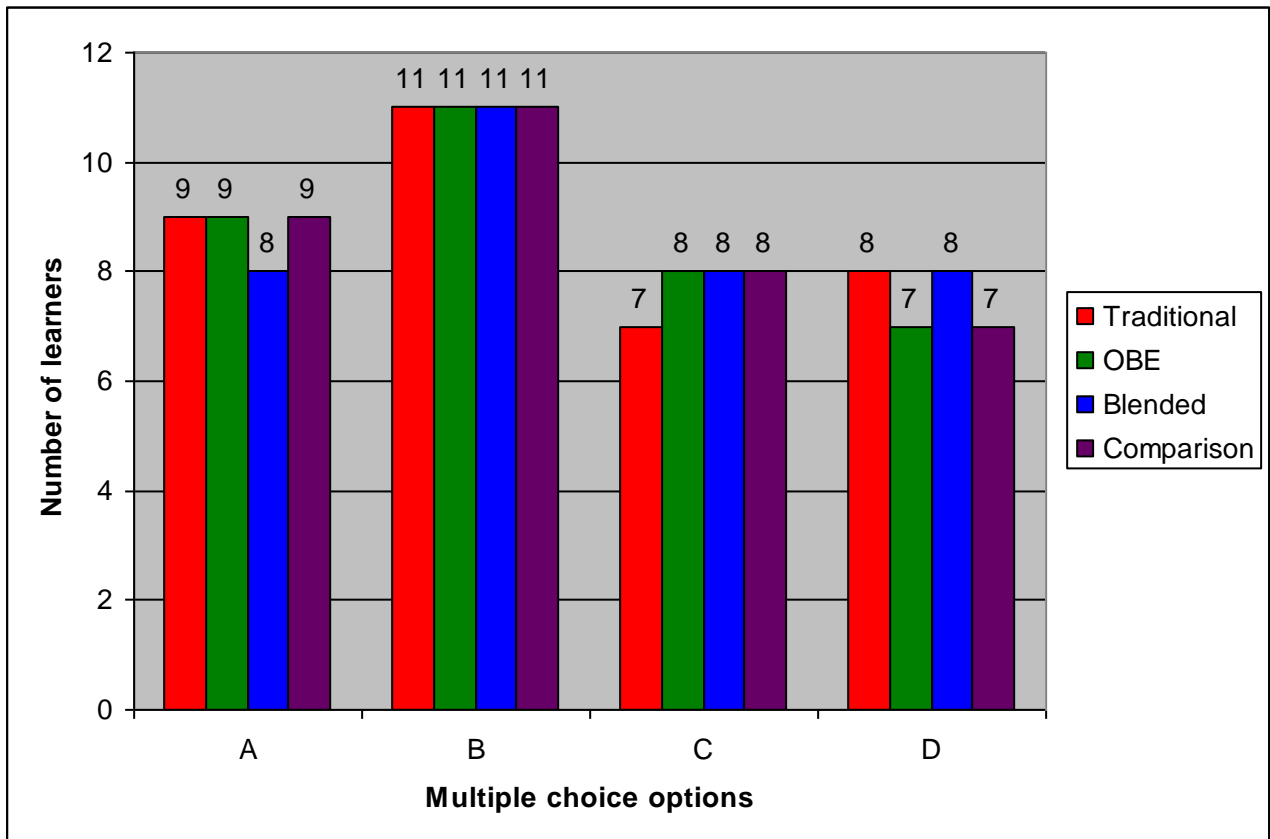
- (iii) Stone that is dropped moves with a **decreasing velocity**.

*"The velocity of the stone decreases as it goes down."*

*"The stone goes down with a decreasing velocity."*

The alternative conceptions (i), (ii) and (iii), appear to come from the lack of understanding the concept of a free fall. For a stone that is dropped, the velocity cannot be constant, neither can it decrease. The stone falls with an increasing velocity and the acceleration due to gravity remains constant.

## QUESTION 21



**Figure 4.22 Number of learners who selected the intended response from the four groups**

Option C was the intended option, although option was the majority option. It is quite clear that the majority of learners did not perform well on this question. Two different alternative conceptions unfolded from the motivations.

**(i) Force** is needed to **keep an object moving** at all times.

*“A force is always needed to keep an object moving”.*

*“an object can only move when there is a force applied”.*

(ii) Force is **same** as pressure.

*“Pressure is the force applied per unit distance which could be to move an object or to stop an object”.*

*“force is same as pressure because it pressurises an object to move”*

*“when you give a pressure to a thing it is forced to do work”.*

The alternative conceptions (i) and (ii) seem to come from the fact that motion is one of the effects of force. Objects can be in motion while the resultant force is zero. There is an exception here, that a force is needed to keep an object moving except for objects that have zero resultant force acting on them. Another alternative conception is that force is confused with pressure. The two quantities are not the same. For example, force is push or pull in a particular direction, whereas pressure is force exerted on a particular area.

## QUESTION 22

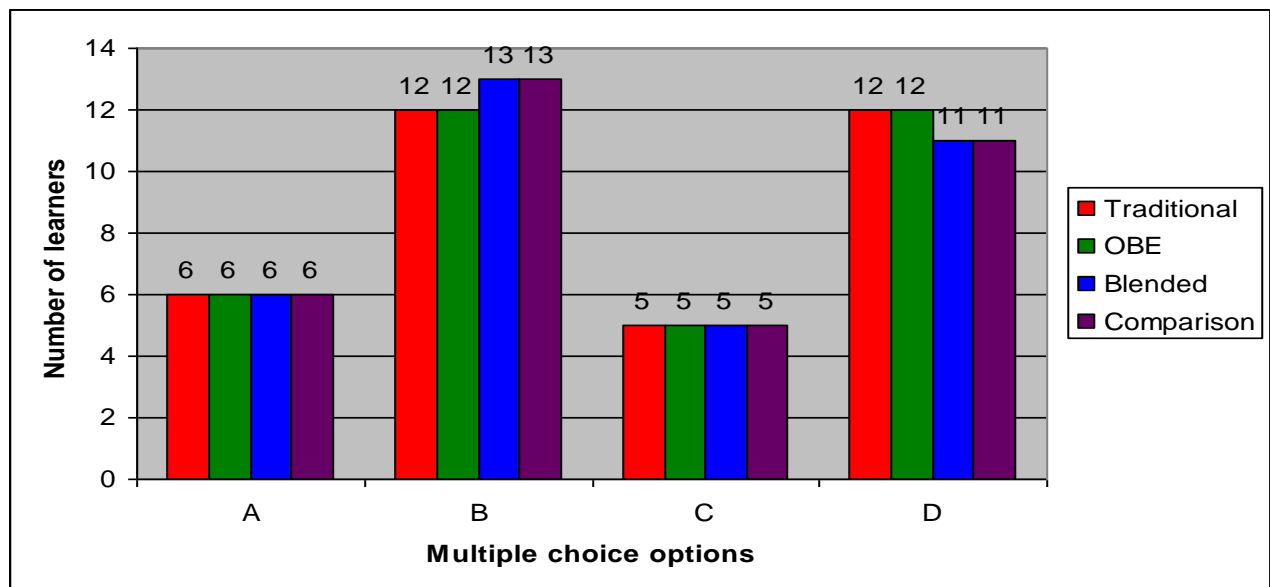


Figure 4.23 Number of learners who selected the intended response from the four groups

Option B was the intended option. It's quite clear that the majority of learners perform well on this question. Nonetheless, two different alternative conceptions unfolded from the motivations.

(i) Both forces are exerted at **different times** for (Newton's Third Law).

*"Because Newton's Third Law agrees that both forces are exerted in different times on different objects".*

*"If object A exerts a force on object B, they will both be exerted at different times"*

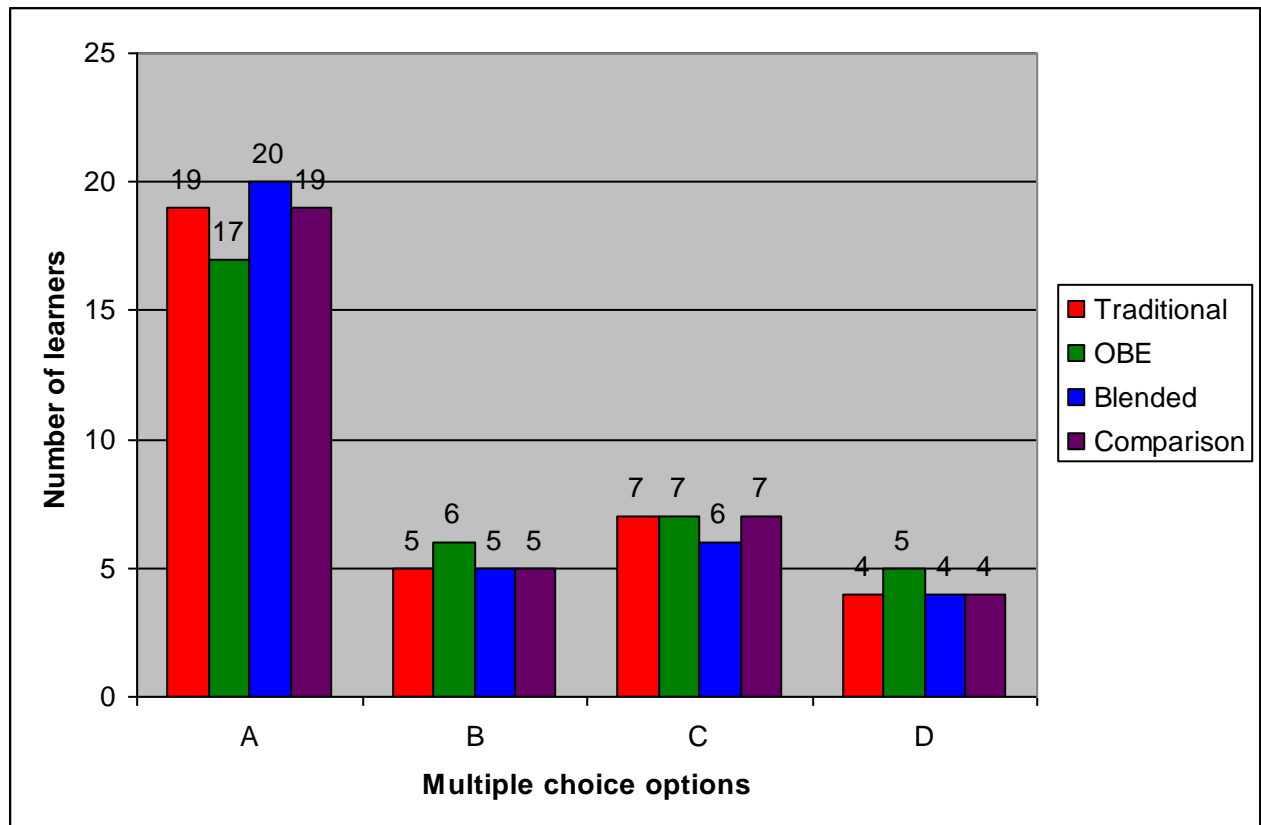
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(ii) Both forces are exerted on the **same object** (Newton's Third Law)

*"If object A exerts the force on object B, it makes happen in the same time and same object according to Newton's Third Law".*

The conceptual difficulties (i) and (ii) appear to emanate from the fact that the statement sounds as if action force is exerted first then reaction force. The law states that "If object A exerts a force on object B, then object B will exert an equal but opposite force on object A". Sometimes the conjunction "then" in this law brings confusion since it brings the idea that action and reaction forces occur at different times. These forces are exerted on two different objects and not on the same object.

### QUESTION 23



**Figure 4.24 Number of learners who selected the intended response from the four groups**

Option A was the intended option and also a majority option. It's quite clear that the majority of learners perform well on this question. Nonetheless, two different alternative conceptions unfolded from the motivations.

(i) Book on the table exerts no force on the table **since it is not moving**.

*"Because both of them are not moving, they both have no weight so they are not exerting any force".*

*"The book is not moving on the table so no force is exerted".*

(ii) Neither the table nor the book exerts a force **since they are both at rest.**

*“They are both at rest and only potential energy is what they have”.*

*“Neither of the table/book exert a force on each other because the book is at rest it cannot exert a force”*

The alternative conceptions (i) and (ii) appear to come from the idea that static object do not exert a force. Force can cause no visible effect. It does not mean that force will only cause motion. For a book on the table, the surface of the table exerts an upward force on the book and the book exerts a downward force on the table.

#### QUESTION 24

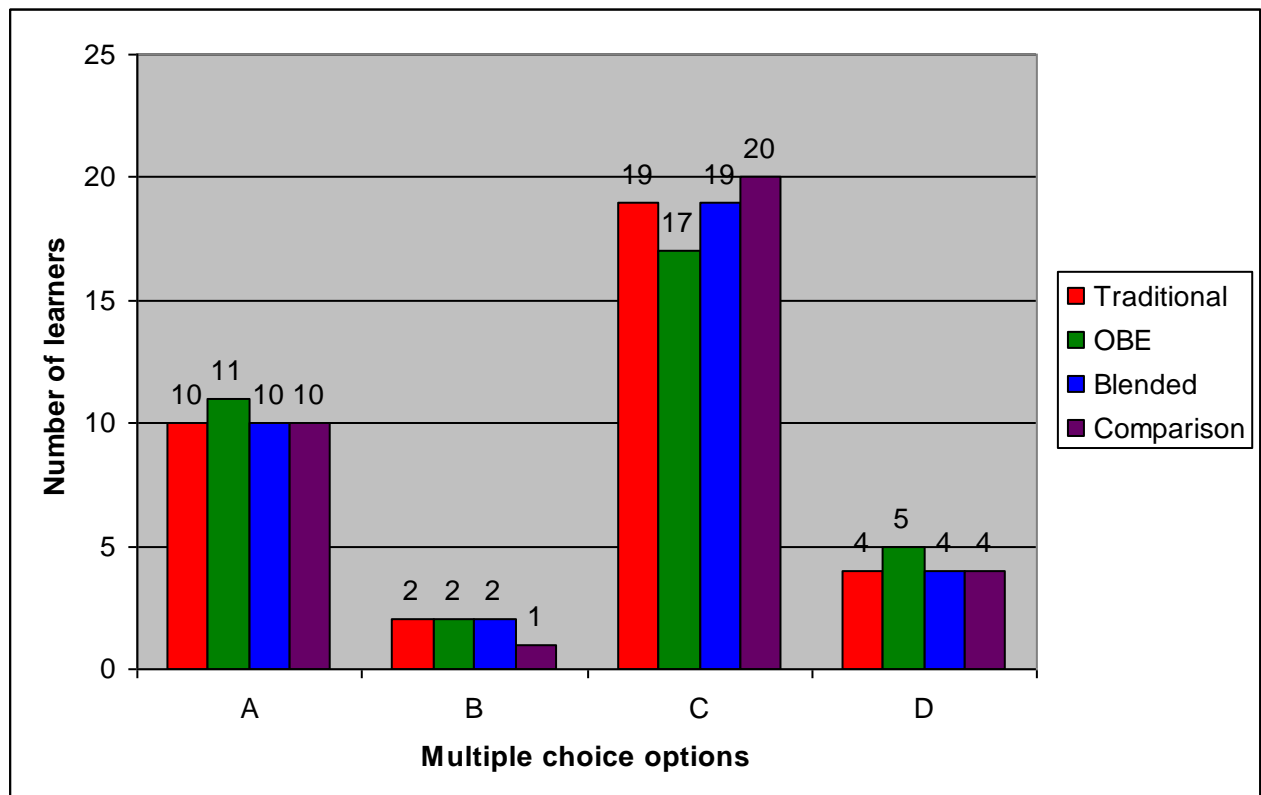


Figure 4.25 Number of learners who selected the intended response from the four groups

Option C was the intended option and also a majority option. It's quite clear that the majority of learners perform well on this question. Nonetheless, two different alternative conceptions unfolded from the motivations.

(i) A stubborn goat pushing against the wall. The wall has a **larger force** than the goat.

*"The force experienced by the wall is more than the force experienced by the goat".*

*"The force exerted on the wall comes back larger".*

*"This is so because the wall applies a greater force than anything else so the force that is applied by the goat is lesser than the force applied by the wall to a goat".*

*"Obviously the wall is stronger than the goat's force".*

*"It is because the goat should have gone through the wall if it was bigger".*

*"The wall does not move, so it is putting much force to the goat as it pushes. The wall exerts a force".*

*"A force that has been applied by a goat is smaller than the force that the wall has got".*

*"Because if the goat had larger force than the wall then, the wall will fall".*

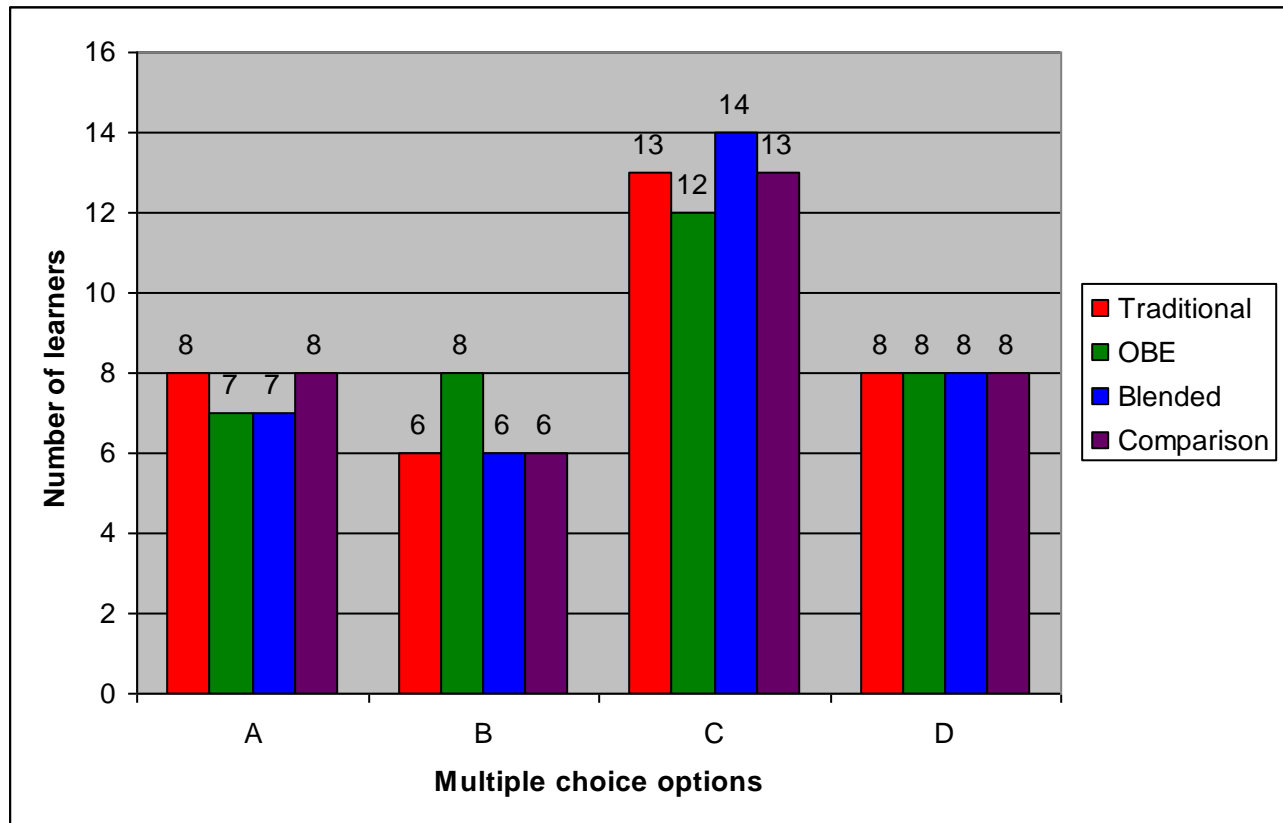
(ii) The goat applies a **larger force** than the wall.

*"The wall is not moving".*

The alternative conceptions (i) and (ii) appear to come from the fact that with regard to Newton's Third Law, learners tend to associate the force exerted with the size of the object. The alternative conception also comes from the fact that the wall is observed as not moving and hence observed as having bigger force.



## QUESTION 25



**Figure 4.26 Number of learners who selected the intended response from the four groups**

Option C was the intended option. Option C was also a majority option. It's quite clear that the majority of learners perform well on this question. Nonetheless, two different alternative conceptions unfolded from the motivations.

(i) Mosquito exerts **larger force** than the monument on the mosquito.

*"Because it is the mosquito that is moving, the monument is just stand still".*

*"Because the mosquito is a moving object and the monument exerts an earth force".*

*"Mosquito has power to force".*

*“Because the mosquito is the one standing on top of the monument there is pushing force.”*

*“The mosquito exerts a larger force on the monument as it is the one which is on the monument”.*

*“I think it is because the monument and the mosquito each exert a force on each other and by that the mosquito exerts the larger force”.*

(ii) Monument exerts **larger force** than the mosquito on the monument.

*“Because the monument has a larger force and does not move as mosquito does.”*

*“The mosquito cannot exert a large force on the monument and it cannot destroy the monument”.*

*“Because the monument is bigger than the mosquito”.*

*“Because the monument is larger than the mosquito”.*

*“I think it is because the mosquito has a smaller weight than the monument”.*

*“I think it is because the mosquito is too small to exert a force.”*

*“A mosquito exerts force on the monument which is less than the force exerted by the tower”.*

*“I am fairly confident because the monument has got a bigger mass as compared to the mosquito and hence the monument exerts a larger force to the mosquito although they both apply a force on each other”.*

*“The monument exerts a larger force from the earth and it is pushing up the mosquito”.*

*“The mosquito has a small force.”*

*“Because the monument is bigger than the mosquito”.*

(iii) **Only the monument** is exerting a force.

*“Because the monument is having a bit of a force than the mosquito.”*

*“ Because the monument has the larger force which means it is the one that exerts a force”.*

*“Because the mosquito has zero mass compared to the monument so only the monument exerts the force on the mosquito”.*

The alternative conceptions (i), (ii) and (iii), appear to come from the fact that learners look at the size of the object. Another alternative conception is same as the one mentioned in the previous question, that static objects do not exert force. They regarded the mosquito as so small that it cannot exert a force on the monument. Another alternative conception here is that since the mosquito is the only object moving, therefore it is the only one exerting the force.

#### 4.4.2 CATEGORIES OF THE MOST PREVALENT ALTERNATIVE CONCEPTIONS

The alternative conceptions, as identified from the quantitative and qualitative analysis of the pre-test questions were categorised. Table 4.6 summarizes the most prevalent alternative conceptions relating to projectile motion, force and static objects. The frequencies in Table 4.6 are indicated as percentage.

Where some alternative conceptions appeared in more than one question, it seemed that these alternative conceptions had a higher frequency than others. From the analysis it was not possible to tell whether the same conception in another question was from the same student or another student in another question. When the questions were constructed, it was not possible to foresee which alternative conceptions would originate from a question. Therefore, some alternative conceptions occur in more than one question and others not. Some of the options of the multiple choice questions indicated alternative conceptions, while others were identified from the motivations.

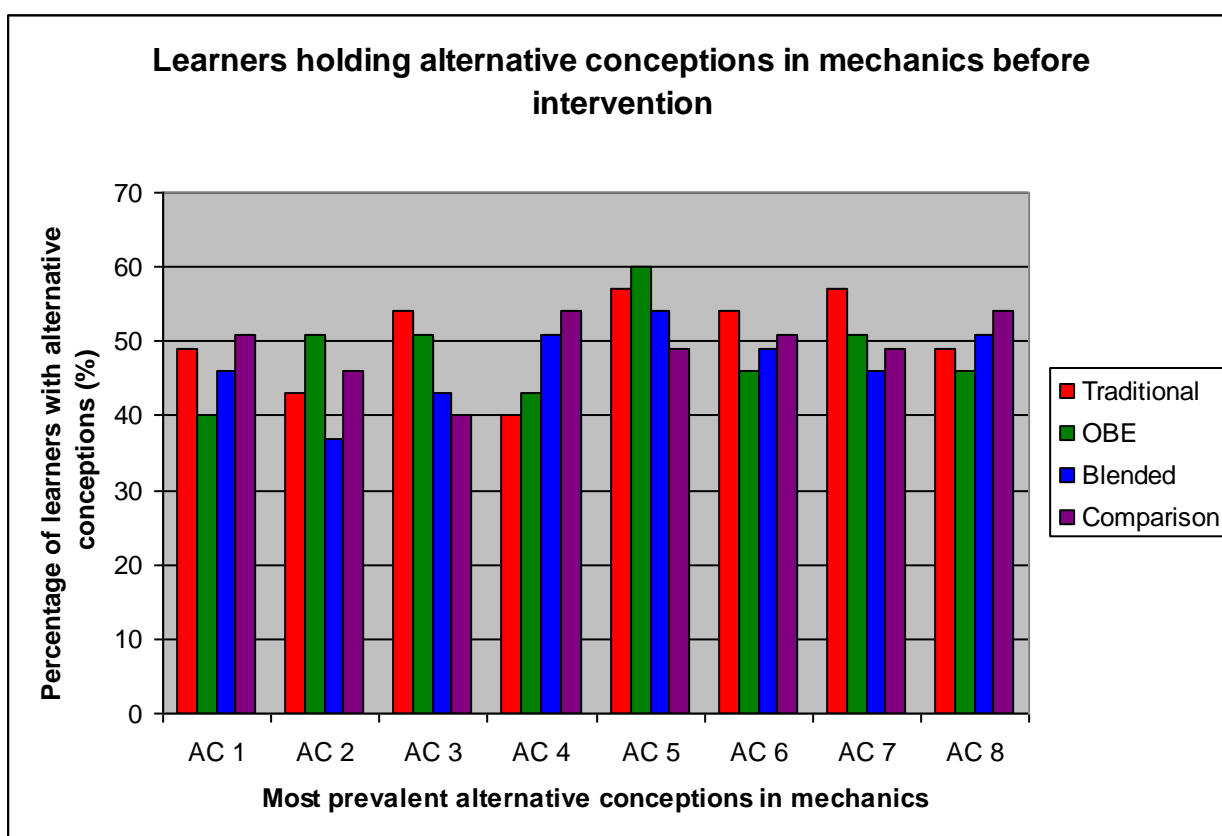
Six categories of alternative conceptions were identified. Each category was assigned a symbol (AC1 to AC8), in no specific order of significance, as explained above. The highest frequency in one question is indicated, although these frequencies do not prioritise the conceptions, as explained above. Table 4.8 summarizes these identified most prevalent alternative conceptions, followed by a discussion of each alternative conception with supporting quotations from the motivations learners gave.

**Table 4.6: Most Prevalent Alternative Conceptions**

Symbol	ALTERNATIVE CONCEPTION	Percentage of learners holding ACs before intervention (%)			
		Trad (35)	OBE (35)	Blend (35)	Comp (35)
AC1	<b>THEME: The Velocity and Acceleration of Projectiles</b> The velocity and acceleration of a projectile increase as it goes upwards.	49	40	46	51
AC2	<b>THEME: Weight/Mass of an Object</b> The weight, or mass, of an object has an effect on the magnitude of the force it exerts.	43	51	37	46
AC3	<b>THEME: Force Concept</b> Force is needed to keep an object moving at all times.	54	51	43	40
AC4	<b>THEME: Objects in Motion</b> Only active agents exert forces	40	43	51	54
AC5	<b>THEME: Static Objects</b> Objects that are not moving do not exert forces.	57	60	54	49
AC6	<b>THEME: Newton's Third Law</b> Action-reaction forces occur at different times.	54	46	49	51
AC7	<b>THEME: Acceleration of Projectiles</b> At the highest point, the acceleration of the projectile is zero	57	51	46	49

AC8	<b>THEME: Active Force</b> Motion implies active force	<b>49</b>	<b>46</b>	<b>51</b>	<b>54</b>
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Table 4.6 indicates eight most prevalent alternative conceptions that emanated from the learners BMT responses. Figure 4.27 summarises the frequency indicated as percentage of the number of learners in the group, for each alternative conceptions in Table 4.6.



**Figure 4.27 Most Prevalent Alternative Conceptions before Intervention**

Figure 4.27 indicates the most prevalent alternative conceptions held by the learners in mechanics before intervention. There were eight alternative conceptions that were identified. The alternative conceptions were about the

kinematical concepts and dynamical concepts. Kinematical concepts were based on the projectile motion, particularly, position, speed, velocity and acceleration. Dynamical concepts were based on force concepts. On average, the percentage for AC 1 to AC 8 for each group was above 40 %, that is, alternative conceptions for both kinematical and dynamical concepts. With regard to kinematical concepts, McCloskey (1983) “postulates that physics students have difficulty in understanding the principles of motion because of intuitive misconceptions” ([www.jstor.org/pss/40025804](http://www.jstor.org/pss/40025804)). He further stated that these alternative conceptions

may occur because of optical illusions experienced when an object’s motion is viewed from certain vantage points. For instance, to someone who is viewing from the ground, an object which is dropped from an airplane may seem to fall straight down because the plane is moving so rapidly that it is ahead of the object when the object hits the ground ([www.jstor.org/pss/40025804](http://www.jstor.org/pss/40025804)).

There are therefore many sources of alternative conceptions but most of them emanate from the learners’ life experiences and other observations.

The following eight sub-sections constitute a summary of the answer to the second research question.

#### **4.4.2.1 AC1: The Velocity and Acceleration of Projectiles**

The alternative conception: *The velocity and acceleration of a projectile increase as it goes up.*

The following were quotes from learners to explain and support the alternative conception:

- “*The velocity increases as the stone goes up*”.
- “*I think acceleration increases as the stone goes up*”.

- *“While the stone is accelerating upwards, the velocity is increasing”.*
- *“As the stone moves vertically upwards, the velocity decreases while the acceleration increases”.*

According to Giancoli (2000:55) “projectile motion refers to the motion of an object that is projected into air at an angle”. In this regard, a projectile is an object (e.g. stone, ball or bullet) that is given an initial velocity by dropping, shooting, throwing or projecting (launching) it, and where the only other force acting on it is due to the force of gravity. Projectiles in motion have zero velocity at their greatest height. Projectiles take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch. In many cases the effect of air resistance is ignored. Again, in many cases the process by which the object is thrown or projected is not the issue of concern. Only the motion of a projectile after it has been projected and moving freely through the air under the action of gravity alone is considered. Thus, the acceleration of the object is that gravity,  $g$ , which acts downward with magnitude  $g = 9.8 \text{ m.s}^{-2}$  (Giancoli, 2000). Gravitational acceleration is the constant acceleration that a free falling object experiences due to gravitational attraction of the earth in the absence of air resistance, whether the object is moving upwards or downwards.

The velocity of the object decreases as it goes upward due to the action of gravity. In the same vein, the velocity of the object increases as it falls freely to the ground or to the thrower’s hand. The acceleration due to gravity is constant and always acts downward. Bueche (1986:46) posits that “like all accelerations, the acceleration due to gravity is a vector. It is directed downward toward the earth”. In this way, falling objects speed up and rising objects slow down (Bueche, 1986). Bueche (1986:46) further opines that “care must be taken in dealing with motion which involves both up and down motion since the proper use of signs is of great importance”. In the same way, Cutnell and Johnson (2010:47) maintain that “during the time the projectile travels

upwards, gravity causes its speed to decrease to zero. On the way down, however, gravity causes the projectile to regain the lost speed.” Regarding the acceleration of the projectile, they aver that “acceleration due to gravity has a constant downward direction and a constant magnitude of  $9.8 \text{ m. s}^{-2}$ . In other words, the acceleration vector... does not behave as the velocity vector does” (Cutnell and Johnson, 2010:47). Based on the above empirical study, conventional science does not support that the velocity and acceleration of projectiles increase as they go upwards.

#### **4.4.2.2 AC2: Weight/Mass of an Object**

The alternative conception: *The weight, or mass, of an object has an effect on the magnitude of the force it exerts.*

This alternative conception was based on question 25 of the TBM (Appendix A): Monument exerts larger force than the mosquito.

The following were quotes from learners to explain and support the alternative conception:

- *Because the monument is bigger than the mosquito.*
- *Because the monument is larger than the mosquito.*
- *I think it is because the mosquito has a smaller weight than the monument.*
- *I think it is because the mosquito is too small to exert a force.*
- *A mosquito exerts force on the monument which is less than the force exerted by the tower.*
- *I am fairly confident because the monument has got a bigger mass as compared to the mosquito and hence the monument exerts a larger force to the mosquito although they both apply a force on each other.*



- *The monument exerts a larger force from the earth and it is pushing up the mosquito.*
- *The mosquito has a small force.*
- *Because the monument is bigger than the mosquito.*

This alternative conception relates to Newton's Third Law. Kirkpatrick and Francis (2010) use the example of ball with a weight of 10 newtons falling freely towards earth. The ball exerts an upward force on the earth of 10 newtons while the earth exerts a downward force on the ball of 10 newtons. These forces are equal in magnitude but opposite in directions. Kirkpatrick and Francis (2010:50) state that "common sense may tell you that earth must exert a larger force because it is so much larger, this is not true." They further posit that "no matter what the origin of the forces, Newton's Third Law tells us that the forces must be equal in size and opposite in direction" (Kirkpatrick & Francis, 2010:51). This illustration explains that the mass or weight of an object has no effect on action-reaction force pair.

#### **4.4.2.3 AC3: Force Concept**

The alternative conception: *Force is needed to keep an object moving at all times.*

The following were quotes from learners to explain and support the alternative conception:

- *"A force is always needed to keep an object moving".*
- *"An object can only move when there is a force applied".*

This alternative conception existed long ago. Tillery, Enger and Ross (2007:29) and Tillery, (2009:32) states that "the Greek philosopher Aristotle incorrectly thought that an object moving across earth's surface requires a continuously

applied force to continue moving.” They further posit that “it took about two thousand years before people began to correctly understand motion” (Tillery, Enger and Ross (2007:29) and Tillery, (2009:32). Force causes motion and force is needed to keep objects in motion but not always. Newton’s First Law states that an object will continue to move with constant velocity in a straight line. This can only happen in the absence of the unbalanced force. When the velocity is constant there is no acceleration and hence zero net force or resultant force. Therefore the object can still move even if the net or resultant force is zero.

#### **4.4.2.4 AC4: Objects in Motion**

The alternative conception: *Only active agents exert force.*

This alternative conception is based on questions 24 and 25 of the TBM (Appendix A): (1) Stubborn goat pushing against the wall and (2) Mosquito landing on top of the monument.

The following were quotes from learners to explain and support the alternative conception:

(1) Stubborn goat pushing against the wall

- *“The goat has a larger force than the wall because the wall is not moving.”*

(2) Mosquito landing on top of the monument.

- *“Because it is the mosquito that is moving, the monument is just stand still.”*

- “Because the mosquito is a moving object and the monument exerts an earth force.”

Terry and Jones (1986:1) state that “pupils’ alternative frameworks and misconceptions about force and motion have been widely reported” ([www.informaworld.com/smpp/content~db=all~content=a747009607](http://www.informaworld.com/smpp/content~db=all~content=a747009607)) Accessed on the 10<sup>th</sup> of June 2011. They further state that the children’s overall understanding of the concept of force and an understanding that underpins the understanding of the Newton’s Third Law, should be a point of concern. According to Newton’s Third Law, stubborn goat pushing against the wall does not mean that the wall is not exerting force against the goat though the wall is not moving. Similarly, the mosquito landing and exerting a force on the monument does not mean that the monument is not exerting a force on the mosquito though the monument is not moving. Question 23 (book resting on the table) of the BMT (Appendix A) is a good example in this regard. Both the book and the table are not moving but it does not mean that there are no forces exerted. Griffith (2007) states that the book exerts a downward force on the table and the table exerts an upward force on the book. The two forces are equal but opposite in directions.

#### **4.4.2.5 AC5: Static Objects**

The alternative conception: *Objects that are not moving do not exert force.*

This alternative conception is based on question 23 of the TBM (Appendix A): Book resting on the table.

The following were quotes from learners indicating alternative conceptions around static objects.

- “Book on the table exerts no force on the table since it is not moving.”

- *“Because both of them are not moving, they both have no weight so they are not exerting any force”.*
- *“The book is not moving on the table so no force is exerted”.*
- *“Neither the table nor the book exerts a force since they are both at rest.”*
- *“Neither of the table/book exert a force on each other because the book is at rest it cannot exert a force”*

Questions 23, 24, and 25 were based on static objects. The purpose of these questions was to overcome the alternative conception that static objects cannot exert forces. Question 23, that is, the question about the book on the table, asked only about the existence of a force from the table. Question 24 and 25 asked about the relative magnitude (or equality) of the forces between other static objects. Each question asked the learners to rate his or her confidence in the answer given; Brown and Clement (1987) state that the common alternative conception is that static objects are unable to exert a force. Learners also maintained that a table does not exert a force upward on a book resting on it.

Giancoli (2000:83) argues that “we tend to associate forces with active bodies such as humans, animals, engines, or a moving object like a hammer”. It does mean that a force is cause by animate objects or moving objects. Even a force itself, when exerted may cause no noticeable effect. In this way, Giancoli (2000) further posits that “it is often difficult to see how an inanimate object at rest, such as a wall or a desk, can exert a force”. Learners could also not see how a table could exert an upward force on the book resting on it. Giancoli (2000:83) gives the following explanation: “every material, no matter how hard, is elastic, at least to some degree...And just as a stretched rubber band exerts a force, so does a stretched (or compressed) wall or desk”. Therefore, a static object does exert a force.

#### 4.4.2.6 AC6: Newton's Third Law of Motion

The alternative conception: *Action-reaction forces occur at different times*

The following were quotes from learners which illustrate this alternative conception:

- *“Because Newton’s Third Law agrees that both forces are exerted in different times on different objects”.*
- *“If object A exerts a force on object B, they will both be exerted at different times”.*
- *“Because Newton’s Third Law agrees that both forces are exerted in different times on different objects”.*
- *“If object A exerts a force on object B, they will both be exerted at different times”.*

Newton’s Third Law states that when pairs of objects interact they exert forces on each other. These forces are equal in size and point in opposite directions.

According to Newton’s Third Law of motion a force pair:

- Will be the same size but in opposite directions;
- Work along the same line;
- Exert a force on two objects;
- Will be of the same force type; and
- Will be exerted at the same time.

Brown and Clement (1987:28) state that “Newton wrote: ‘Whatever draws or presses another is as much drawn or pressed by that other’”. Furthermore, Kirkpatrick and Francis (2010:50) state that Newton also wrote: “If you press a stone with your finger, the finger is also pressed by the stone”. According to Brown and Clement (1987:28)

This statement suggests that forces always arise as a result of mutual actions ('interactions') between objects. If object A pushes or pulls on object B, then at the same time object B pushes or pulls with precisely equal force on A. These paired pulls and pushes are always equal in magnitude, opposite in directions, and on two different objects.

Brown and Clement (1987) further posit that Newton's Third Law is about action-reaction pair. It makes no difference which force you call the action and which the reaction, because they occur at exactly the same time. The action does not 'cause' the reaction. Action and reaction coexist. You cannot have one without the other. Most important, the two forces are not acting on the same object. In same vein, Kirkpatrick and Francis (2010:50) state that "because the two forces are equivalent, it doesn't matter which one is called the action and which the reaction."

#### **4.4.2.7 AC7: Acceleration of Projectiles**

The alternative conception: *At the highest point, the acceleration of a projectile is zero.*

The following were quotes from learners which illustrate this alternative conception:

- *"The acceleration of the stone decreases and become zero at the highest turning point"*
- *"The acceleration increases during free fall of the stone."*

For projectile motion, Giancoli (2000) states that the acceleration of the object act downward with magnitude  $g = 9.8 \text{ m.s}^{-2}$ . As stated in AC1 above, Giancoli (2000) further posits that gravitational acceleration is the constant acceleration that a free falling object experiences due to gravitational attraction of the earth in the absence of air resistance, whether the object is moving upwards or

downwards. Cutnell and Johnson (2010) state that it is the velocity of the projectile that becomes zero at the highest point. They further maintain that “the acceleration vector is not zero at the top of the motional path just because the velocity vector is zero there” (Cutnell and Johnson, 2010:46). By way of definition, “acceleration is the rate at which the velocity is changing, and the velocity is changing at the top even though at one instant it is zero” (Cutnell & Johnson, 2010:46). The empirical study also indicates that it is an alternative conception to say the acceleration of a projectile is zero at the highest point (Giancoli, 2000).

#### **4.4.2.8 AC8: Active Force**

The alternative conception: *Motion implies active force.*

This alternative conception is based on question 23 and 25 of the BTM:

(1) Book resting on the table and (2) Mosquito landing on the monument.

The following were quotes from learners which illustrate this alternative conception:

(1) Book resting on the table

No motion no force

- *“Because both of them are not moving, they both have no weight so they are not exerting any force”.*
- *“The book is not moving on the table so no force is exerted”.*

(2) Mosquito landing on the monument.

Mosquito exerts larger force:

- *“Because it is the mosquito that is moving, the monument is just stand still.”*

- *“Because the mosquito is a moving object and the monument exerts an earth force.”*
- *“Mosquito has power to force.”*
- *“Because the mosquito is the one standing on top of the monument there is pushing force.”*

Hestenes, Wells and Swackhamer (1992) in their study also found that students had an alternative conception about force concept, particularly active force producing motion. Hestenes, et al, (1992) state that active force is an alternative conception that corresponds most closely to Newton’s Second Law of motion. Question 24 of the BTM (Appendix A) is a good example in this regard: “A stubborn goat is pushing against a wall.” There is an active force exerted by the goat but the wall does not move. A goat is an active agent. This means that “active forces have their limits, that is, a limited capacity to produce motion” (Hestenes, et al, 1992). This means that a may cause no noticeable effect when exerted on the object.

## 4.5 INTERVENTIONS DEVELOPED AND IMPLEMENTED

**A curriculum intervention, based on traditional, OBE and blended approaches, to redress the identified conceptual difficulties and alternative conceptions were developed and implemented.**

### 4.5.1 TRADITIONAL INTERVENTION

Regarding the traditional group, the concepts were treated in the traditional way of teaching, which involved chalk and talk, i.e. lecturing, writing notes on the chalkboard and the use of the prescribed textbook as the only reference.



Learners had to listen and only talk when answering the teacher's questions. Empirical study reveals that listening, talking or reading can involve active participation by the learner when making connections between aspects of that situation and his/her prior knowledge (Driver & Oldham, 1986; as cited by Coetzee, 2008). Because the aim of this intervention was to be a "traditional lecture" intervention, the interactive engagement methods of learners were limited.

The teacher was regarded as the transmitter of information. He was also in complete control of the classroom proceedings. Learners were passive recipients of information. There was little interaction and communication among the learners.

#### 4.5.2 OBE INTERVENTION

With regard to the OBE group, the concepts were treated according to the OBE approach (constructivist way of teaching and learning), which was mainly learner-centred. Interactive engagement methods were used in this approach.

The variety of instructional methods was used during the OBE intervention. Learning was almost learner-centred. The students participated fully in the programme by handing in assignments, having group discussions, giving feedback by transparencies on the overhead projector, observing, and other. This intervention did not rely on one, prescribed textbook as the only source of information. Learners were motivated and encouraged to use other sources in addition to the prescribed textbook. The planned activities were aimed at encouraging students to change their ideas in useful and intended ways by engaging them in activities which encouraged them to construct scientific ideas for themselves, and challenge their pre-existing conceptions. This was done to promote interactive engagement of the learners so as to deal with the alternative and conceptual difficulties in mechanics.

The teacher was regarded as a facilitator of learning. Teaching was in a constructivistic way. Instruction was learner-centred. Learner-learner interactions were promoted through group discussions and peer assessment.

#### 4.5.3 BLENDED INTERVENTION

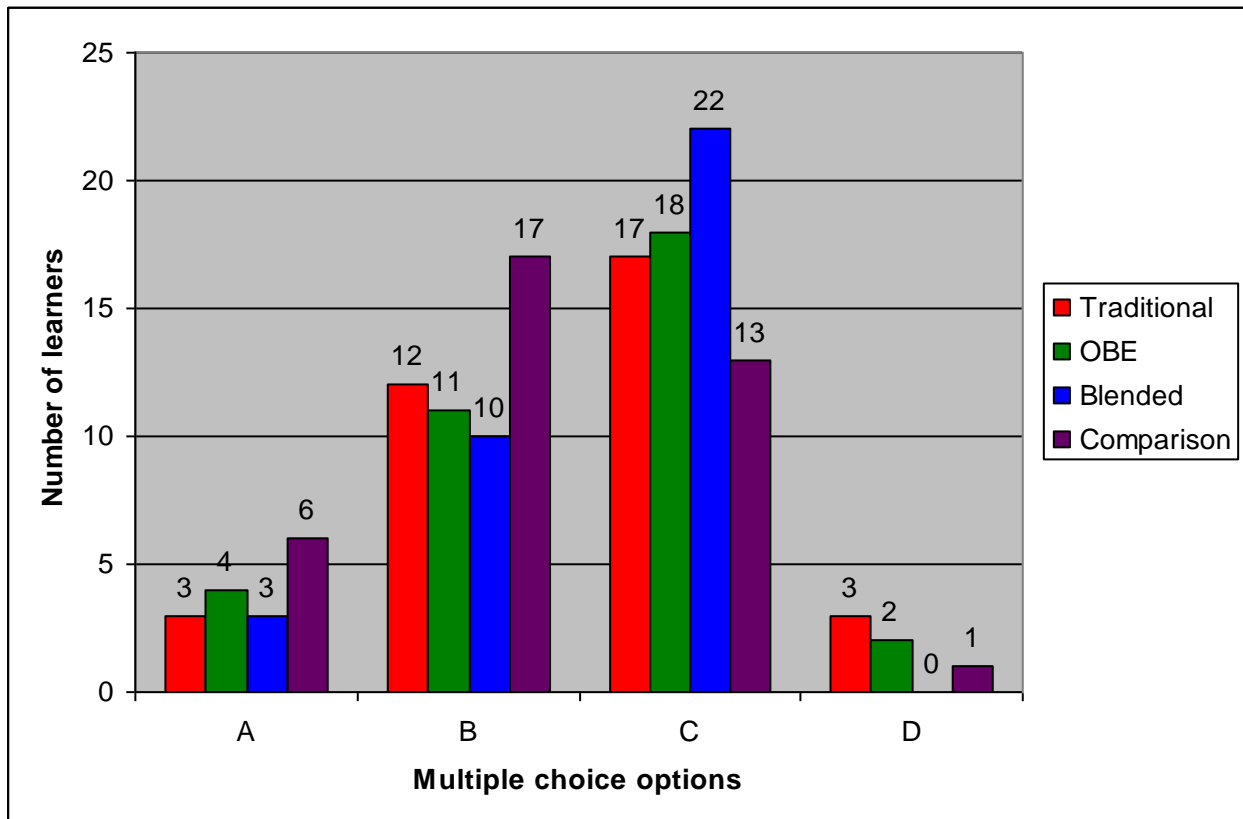
For the blended group, a variety of teaching methods were used for the benefit of the learners. No specific method was regarded as more important than other methods. Telling method was used sometimes to introduce the concepts and/or to explain some most difficult concepts. Learners were also given work to search through the internet at home or using their cell phones. By so doing, learners were taught how to use their cell phone for their academic benefit. Group work and discussion were also other methods of teaching used.

The teacher served as a facilitator of learning, researcher (web-based, as well as a learner too. Learning was learner-centred though the lecture method was also used to introduce concepts and other aspects where it was deemed necessary. Interactive engagement of learners was promoted mainly through group discussions.

#### **4.5.4 Quantitative and Qualitative Analysis of the Post-test for Conceptual Difficulties in Mechanics**

Figures 4.28 to 4.42 show the graphs of the number of learners from the experimental groups (traditional, OBE and blended) as well as the comparison group, who chose options A, B, C and D in the Basic Mechanics Test (BMT) for post-test. However, for each group a number of conceptual difficulties still persisted even after the intervention. Again, each figure below reflects that there was no significant change for the comparison group between the pre- and post-tests.

### Question 1



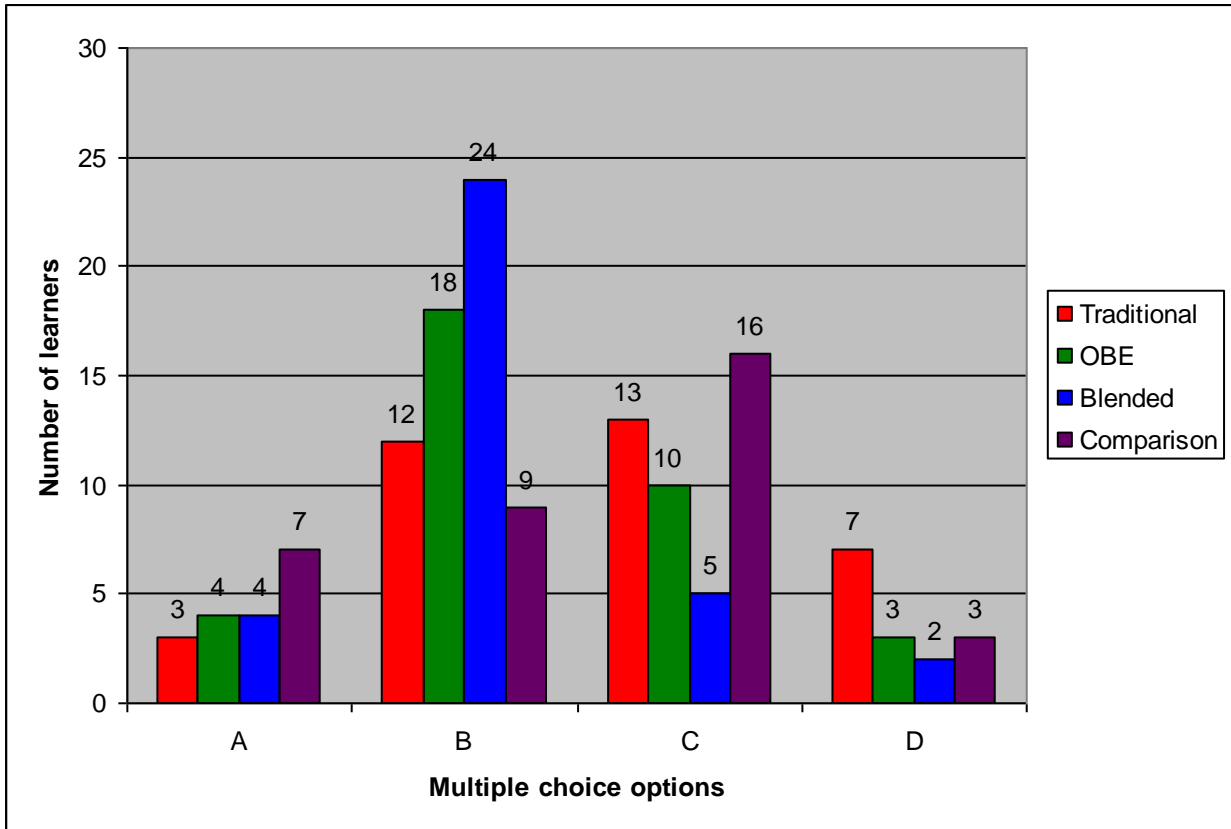
**Figure 4.28 Number of Learners who selected the intended Response from the four groups**

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to work and energy particularly, work done by frictional force.

Figure 4.28 shows that the number of learners who selected the correct option was 22 for the blended group, 18 for the OBE group, 17 for the traditional group and 13 for the comparison group. Among the intervention groups, the blended

group had the highest number of learners who selected the intended option followed by the OBE group.

## Question 2

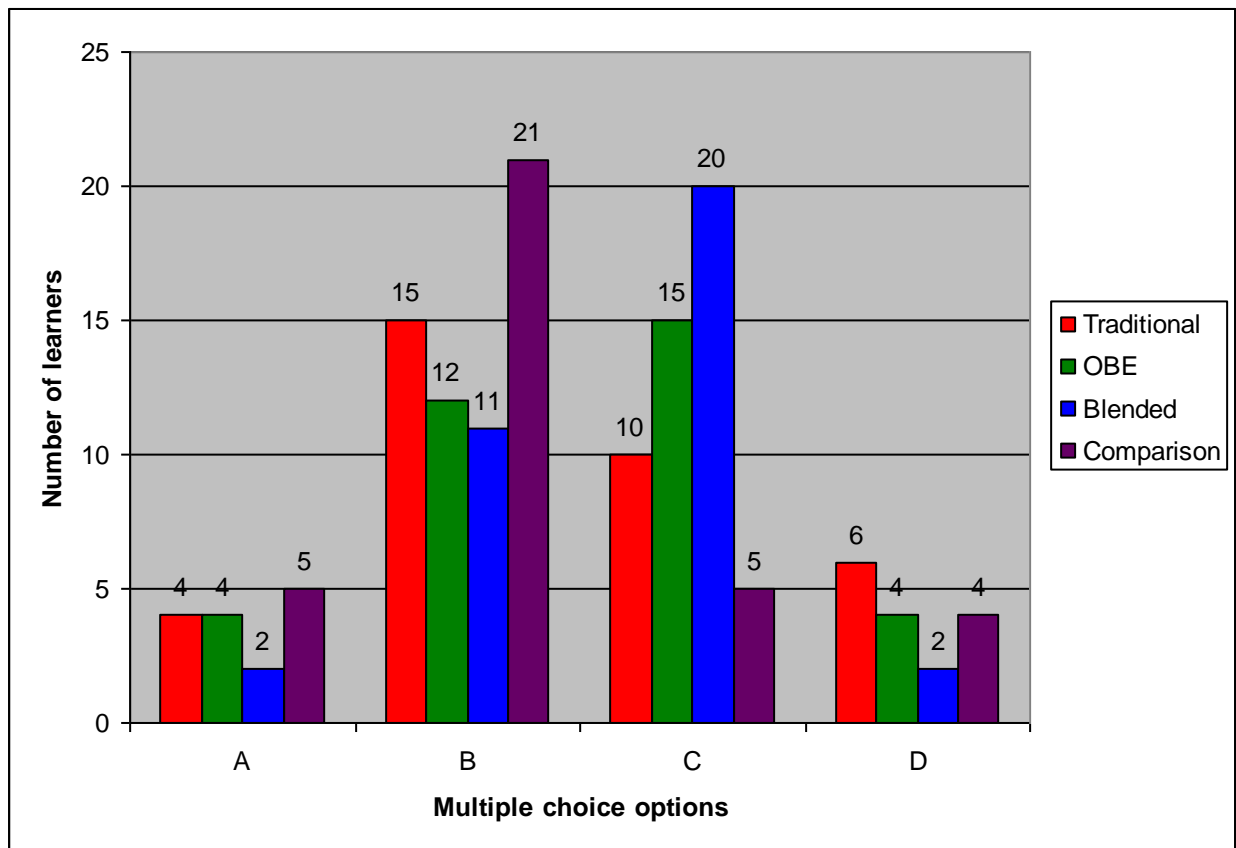


**Figure 4.29 Number of Learners who selected the intended Response from the four groups**

Option B was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to work and energy particularly, the work-energy theorem.

Figure 4.29 shows that the number of learners who selected the correct option was 24 for the blended group, 18 for the OBE group, 12 for the traditional group and 9 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 3



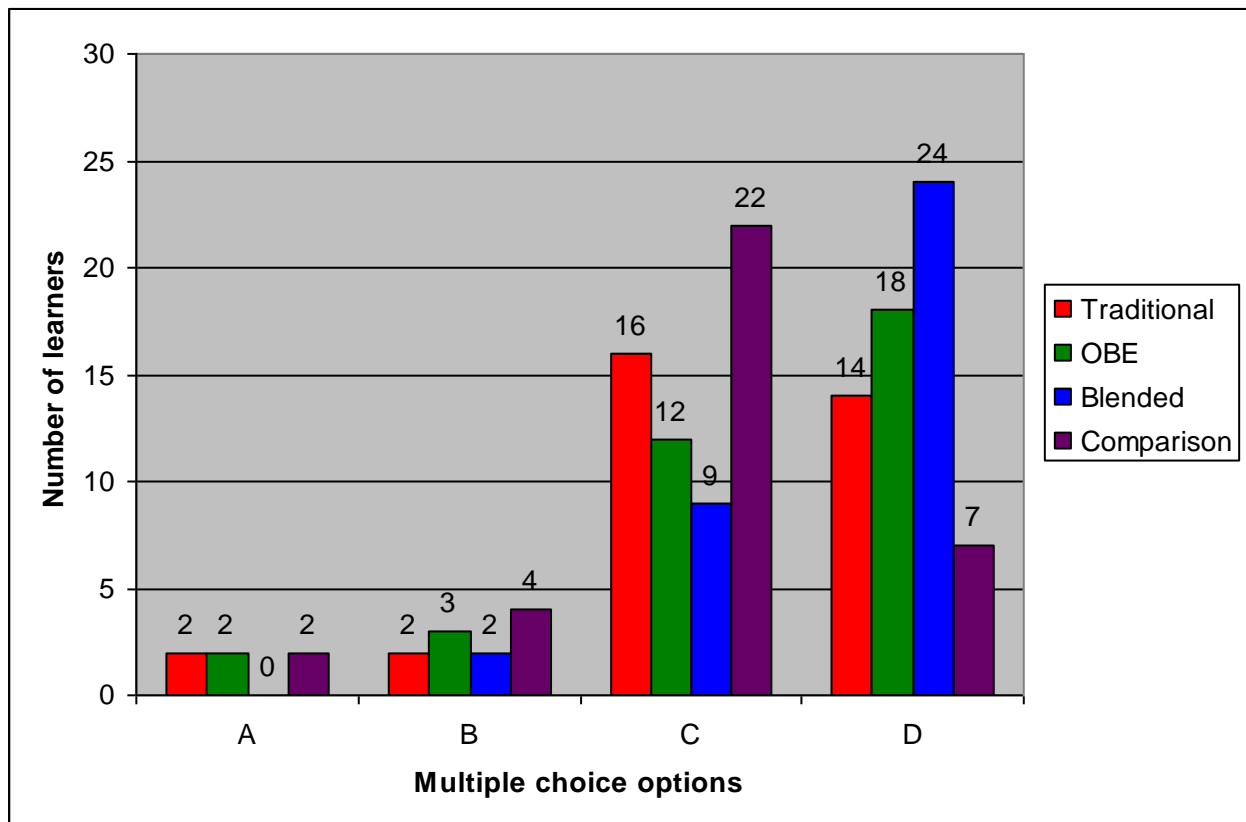
**Figure 4.30 Number of Learners who selected the intended Response from the four groups**

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some

learners there was still a conceptual difficulty with regard to work and energy particularly, the application of the work-energy theorem.

Figure 4.30 shows that the number of learners who selected the correct option was 20 for the blended group, 15 for the OBE group, 10 for the traditional group and 5 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

#### Question 4



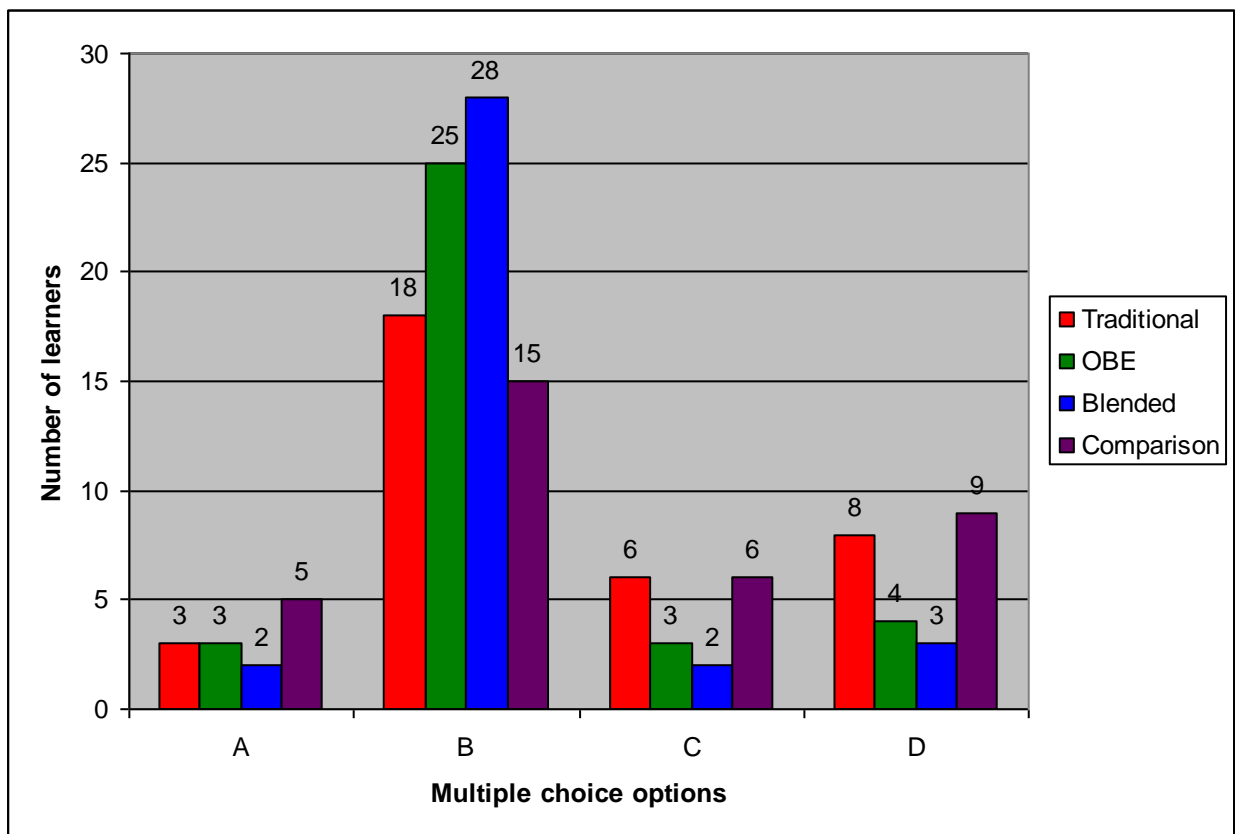
**Figure 4.31 Number of Learners who selected the intended Response from the four groups**

Option D was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the

intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to kinetic energy particularly, the relationship among kinetic energy, mass and the velocity of an object in the kinetic energy equation.

Figure 4.31 shows that the number of learners who selected the correct option was 24 for the blended group, 18 for the OBE group, 14 for the traditional group and 7 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 5

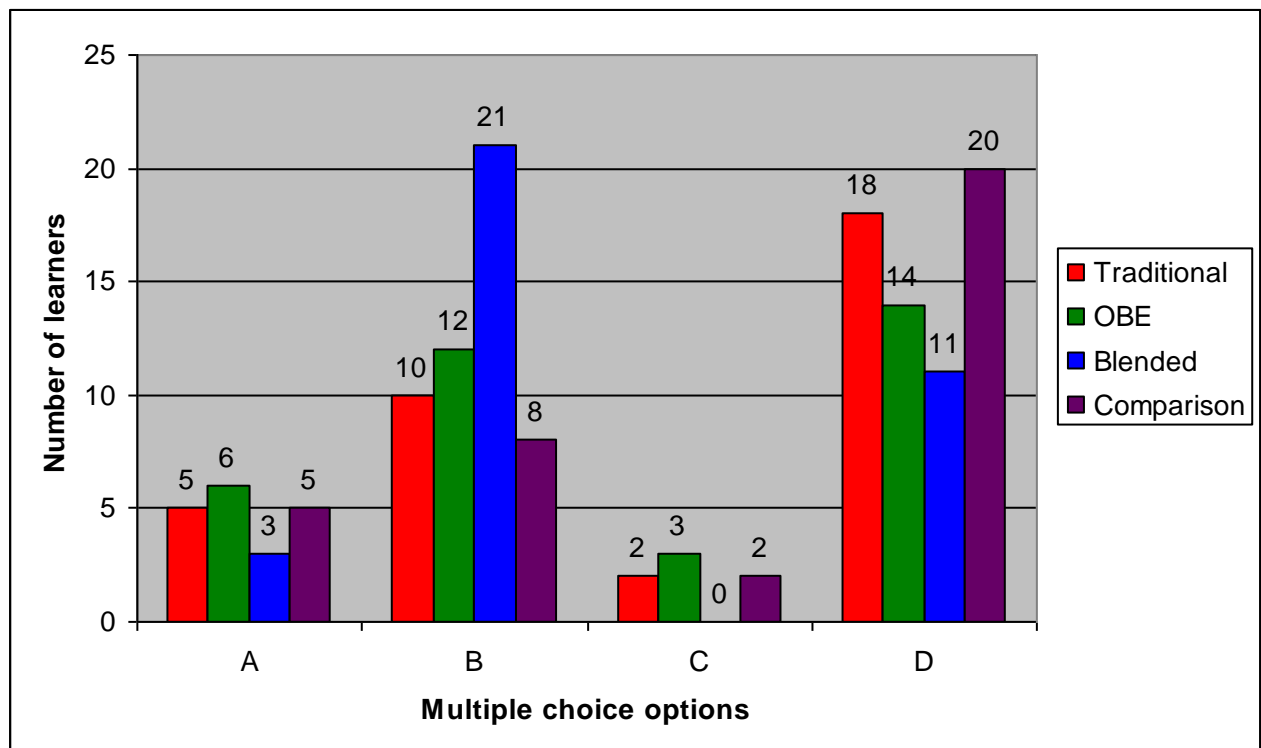


**Figure 4.32** Number of Learners who selected the intended Response from the four groups

Option B was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to *work* and *energy* particularly, *work* done by frictional force (negative work) as well as determining the angle between the frictional force and the displacement.

Figure 4.32 shows that the number of learners who selected the correct option was 28 for the blended group, 25 for the OBE group, 18 for the traditional group and 15 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 6



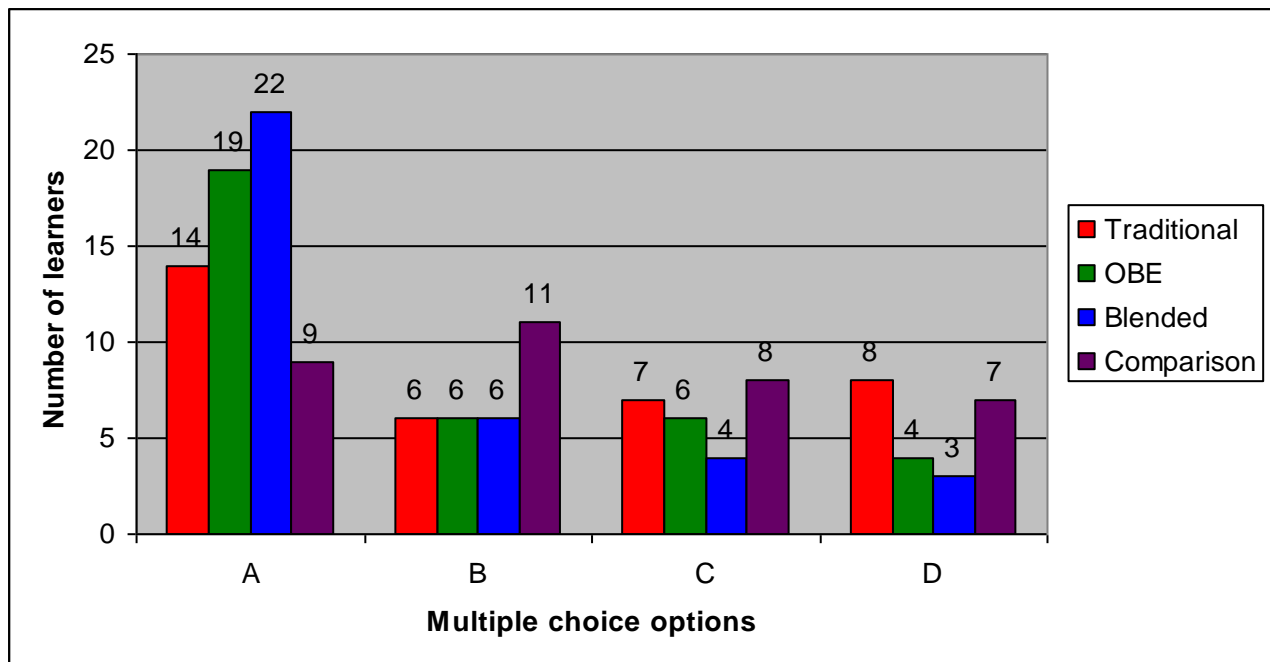
**Figure 4.33** Number of Learners who selected the intended Response from the four groups



Option B was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to force concept particularly, the concept of the net force and forces in equilibrium (balanced forces).

Figure 4.33 shows that the number of learners who selected the correct option was 21 for the blended group, 12 for the OBE group, 10 for the traditional group and 8 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 7

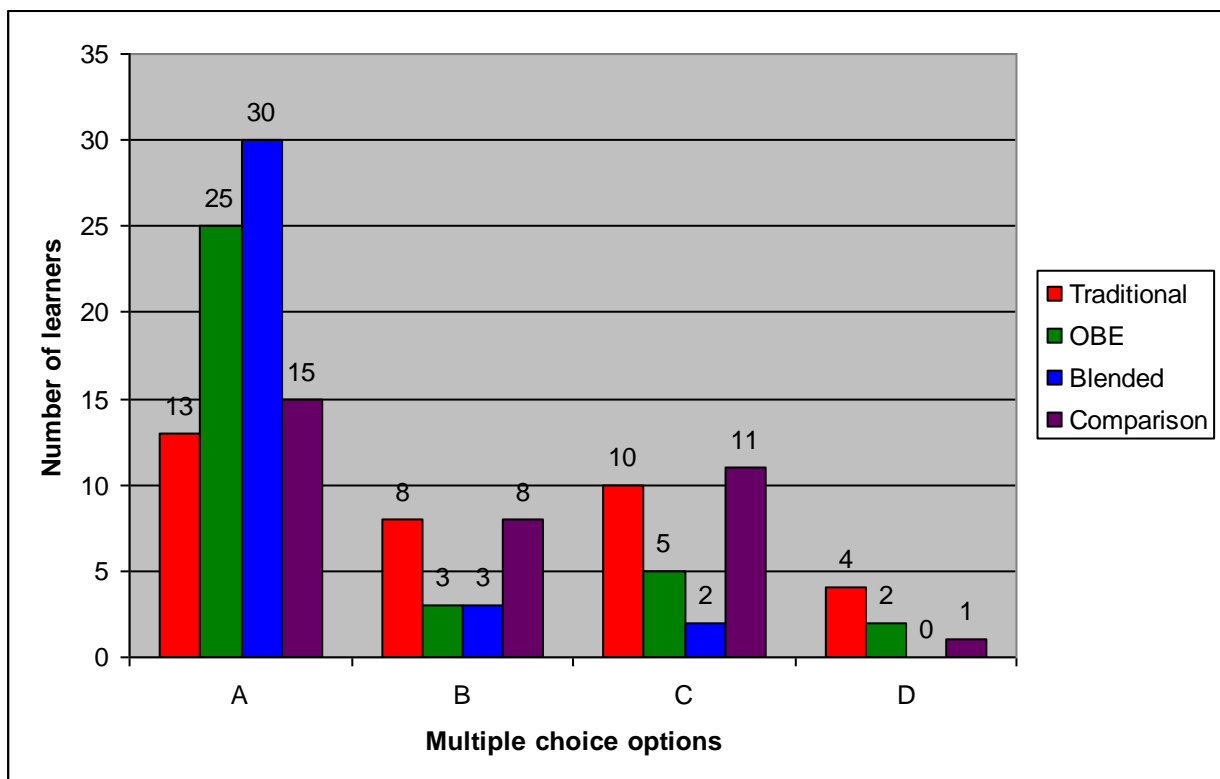


**Figure 4.34** Number of Learners who selected the intended Response from the four groups

Option A was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to work concept particularly, work done by the normal force (zero work).

Figure 4.34 shows that the number of learners who selected the correct option was 22 for the blended group, 19 for the OBE group, 14 for the traditional group and 9 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 8

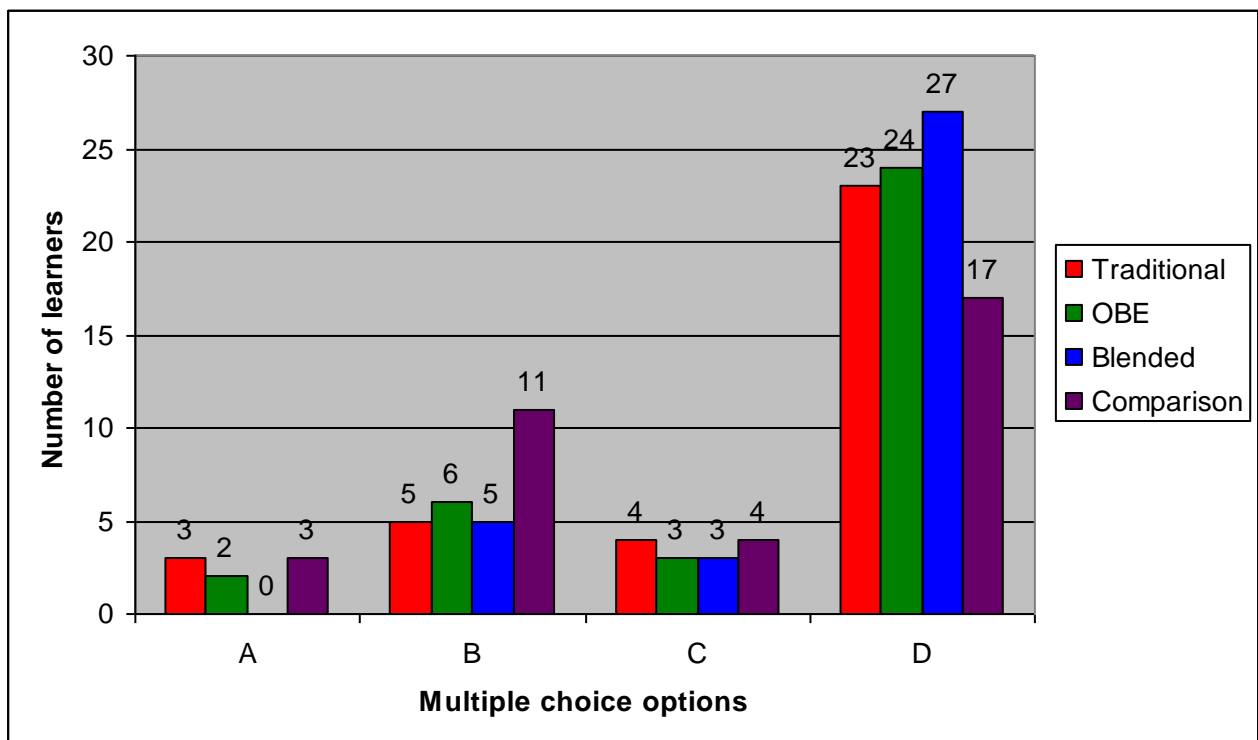


**Figure 4.35** Number of Learners who selected the intended Response from the four groups

Option A was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard finding the components of the weight particularly, finding the net force parallel to the slope.

Figure 4.35 shows that the number of learners who selected the correct option was 30 for the blended group, 25 for the OBE group, 13 for the traditional group and 15 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 9

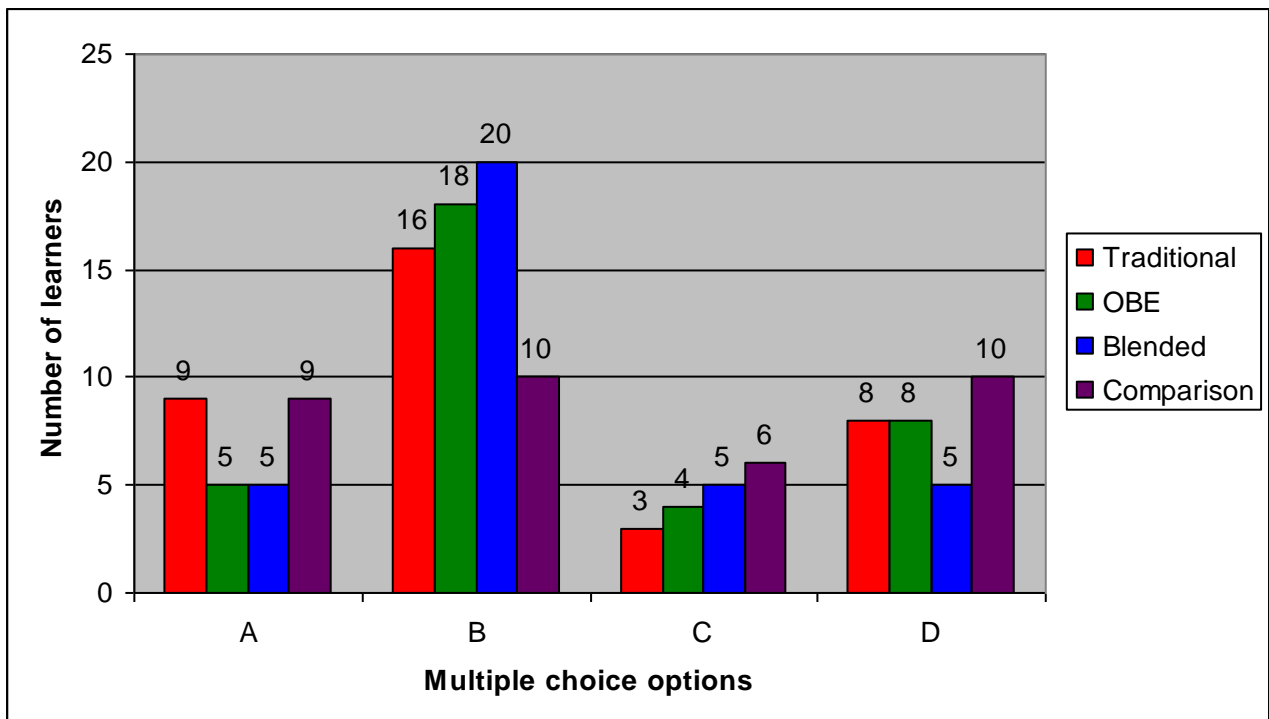


**Figure 4.36** Number of Learners who selected the intended Response from the four groups

Option D was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to work and energy particularly, finding the kinetic energy by first finding the velocity of the sliding object (motion on the inclined surface).

Figure 4.36 shows that the number of learners who selected the correct option was 27 for the blended group, 24 for the OBE group, 23 for the traditional group and 17 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

#### Question 10

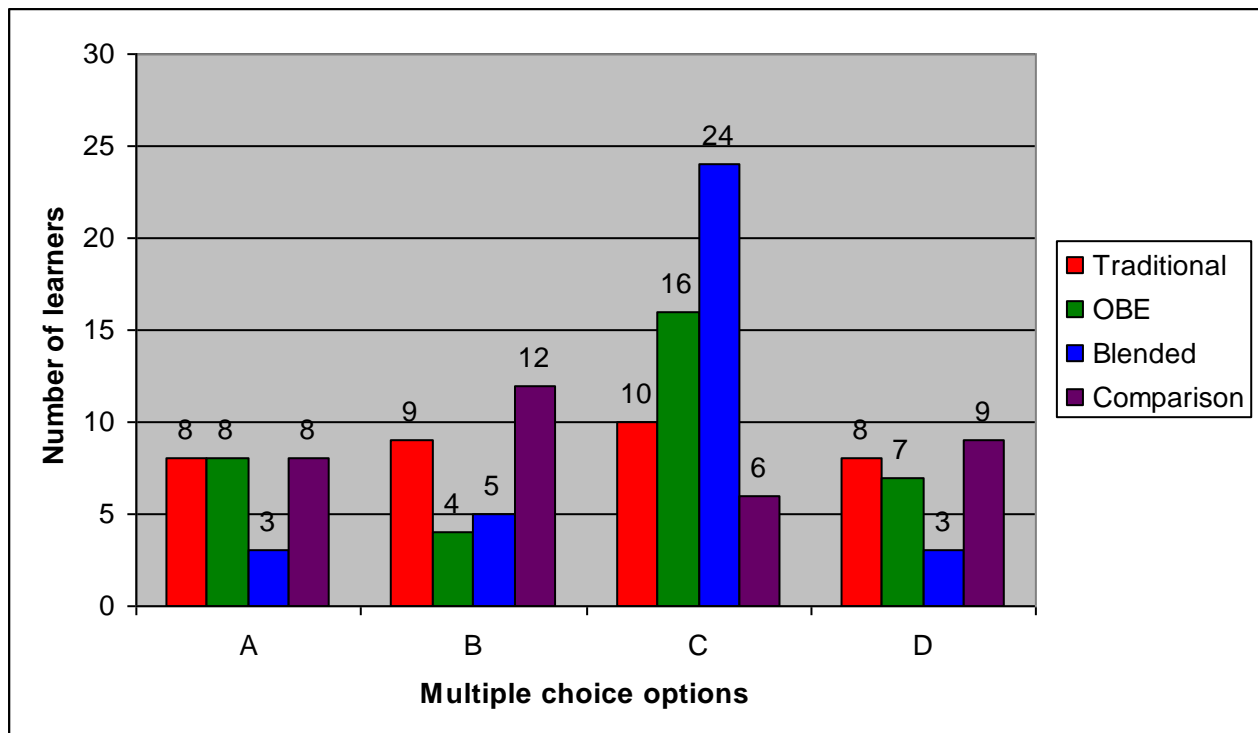


**Figure 4.37** Number of Learners who selected the intended Response from the four groups

Option B was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to motion on the inclined surface particularly, resolving the components of the weight and finding the work done by the gravitational force.

Figure 4.37 shows that the number of learners who selected the correct option was 20 for the blended group, 18 for the OBE group, 16 for the traditional group and 10 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

#### Question 11

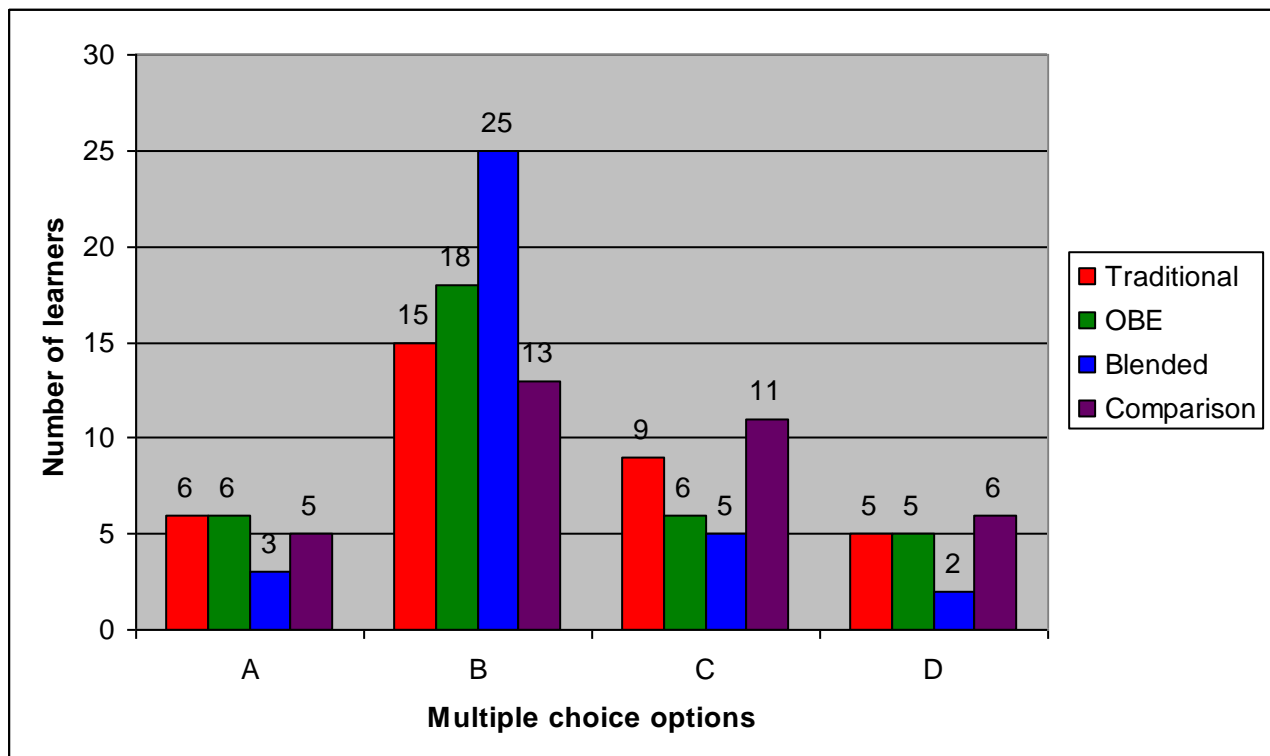


**Figure 4.38** Number of Learners who selected the intended Response from the four groups

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to work and energy for motion on the inclined surface particularly, resolving the components of the weight and finding the work done by frictional force.

Figure 4.38 shows that the number of learners who selected the correct option was 24 for the blended group, 16 for the OBE group, 10 for the traditional group and 6 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 12

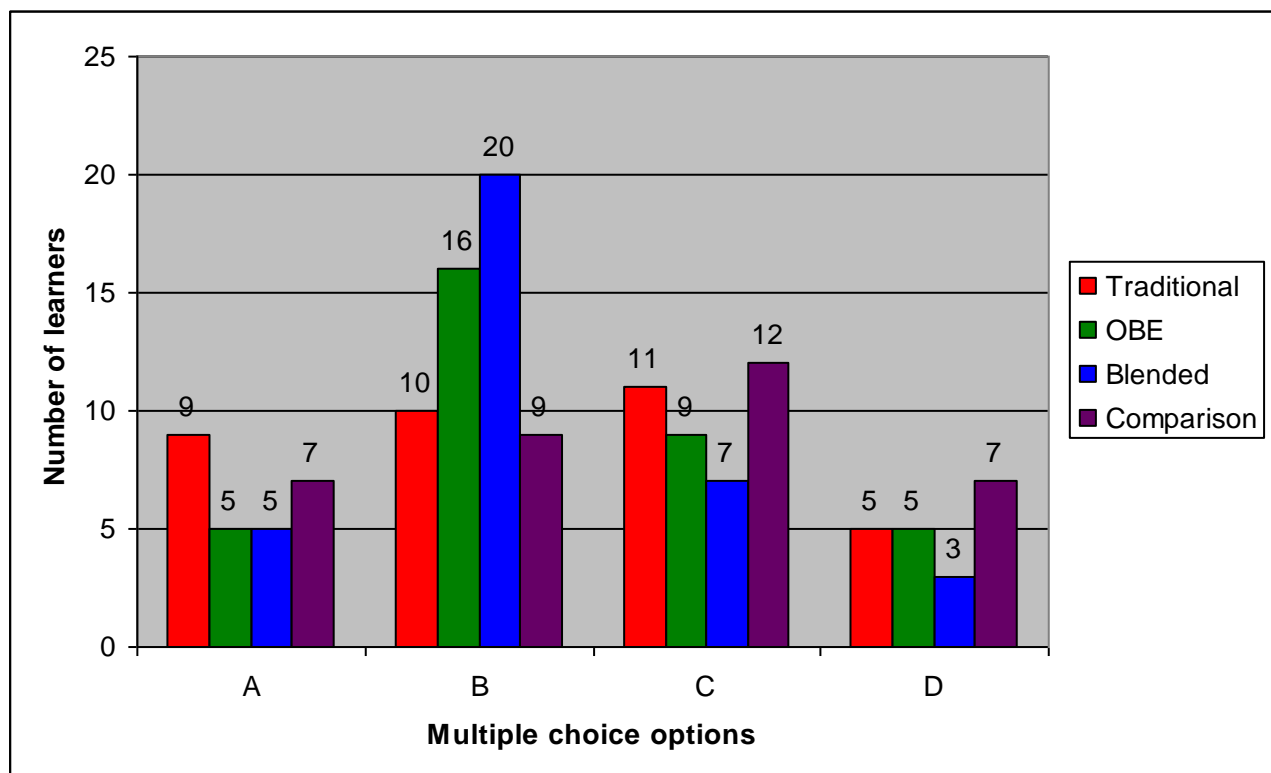


**Figure 4.39** Number of Learners who selected the intended Response from the four groups

Option B was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to force concept particularly, finding the magnitude (only the size) of frictional force.

Figure 4.39 shows that the number of learners who selected the correct option was 25 for the blended group, 18 for the OBE group, 15 for the traditional group and 13 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### Question 13

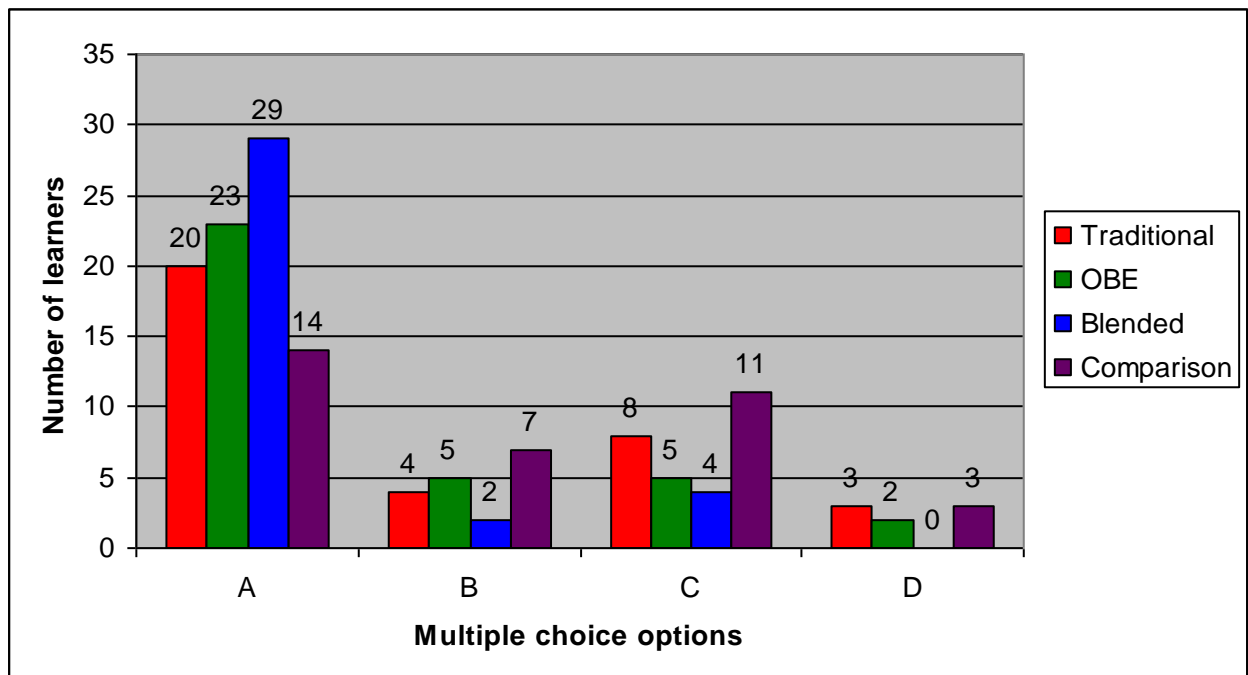


**Figure 4.40** Number of Learners who selected the intended Response from the four groups

Option B was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to work and energy particularly, the application of the Principle of Conservation of Mechanical Energy.

Figure 4.40 shows that the number of learners who selected the correct option was 20 for the blended group, 16 for the OBE group, 10 for the traditional group and 9 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

#### Question 14



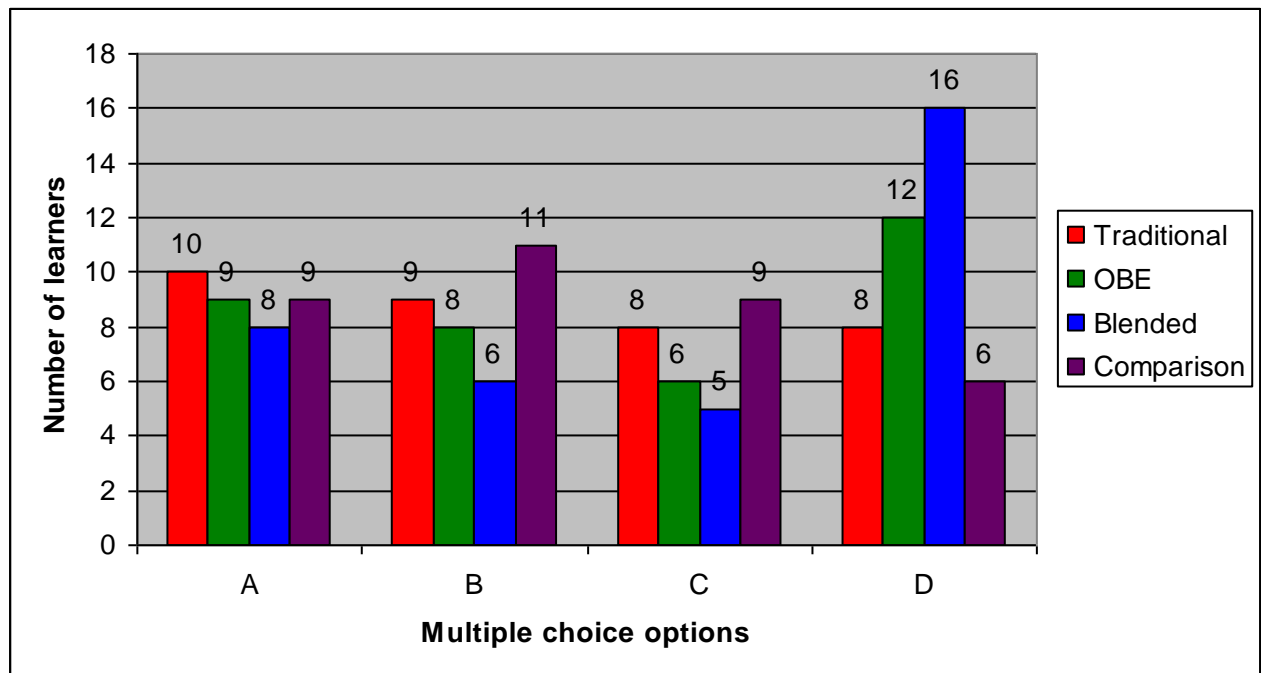
**Figure 4.41** Number of Learners who selected the intended Response from the four groups



Option A was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to kinetic energy concept particularly, finding the kinetic energy for the motion on the inclined surface.

Figure 4.41 shows that the number of learners who selected the correct option was 29 for the blended group, 23 for the OBE group, 20 for the traditional group and 14 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

#### Question 15



**Figure 4.42** Number of Learners who selected the intended Response from the four groups

Option D was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some conceptual difficulties still persisted. To some learners there was still a conceptual difficulty with regard to work and energy for the motion on the inclined surface particularly, finding kinetic energy at the top of the ramp.

Figure 4.42 shows that the number of learners who selected the correct option was 16 for the blended group, 12 for the OBE group, 8 for the traditional group and 6 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

#### **4.5.5 Alleviation of Conceptual Difficulties**

The frequency of the identified most prevalent conceptual difficulties, was determined following the traditional, OBE and the blended interventions. The effectiveness of the interventions in overcoming or alleviating the conceptual difficulties was compared.

Table 4.7 summarises the frequency indicated as percentage of the number learners in each group, for each conceptual difficulty (CD). The traditional group is indicated in **red**, OBE group in **green**, blended group in **blue** and comparison group in **purple**. For each of comparison, the original percentages before the interventions (i.e. from Table 4.5) are indicated in brackets.

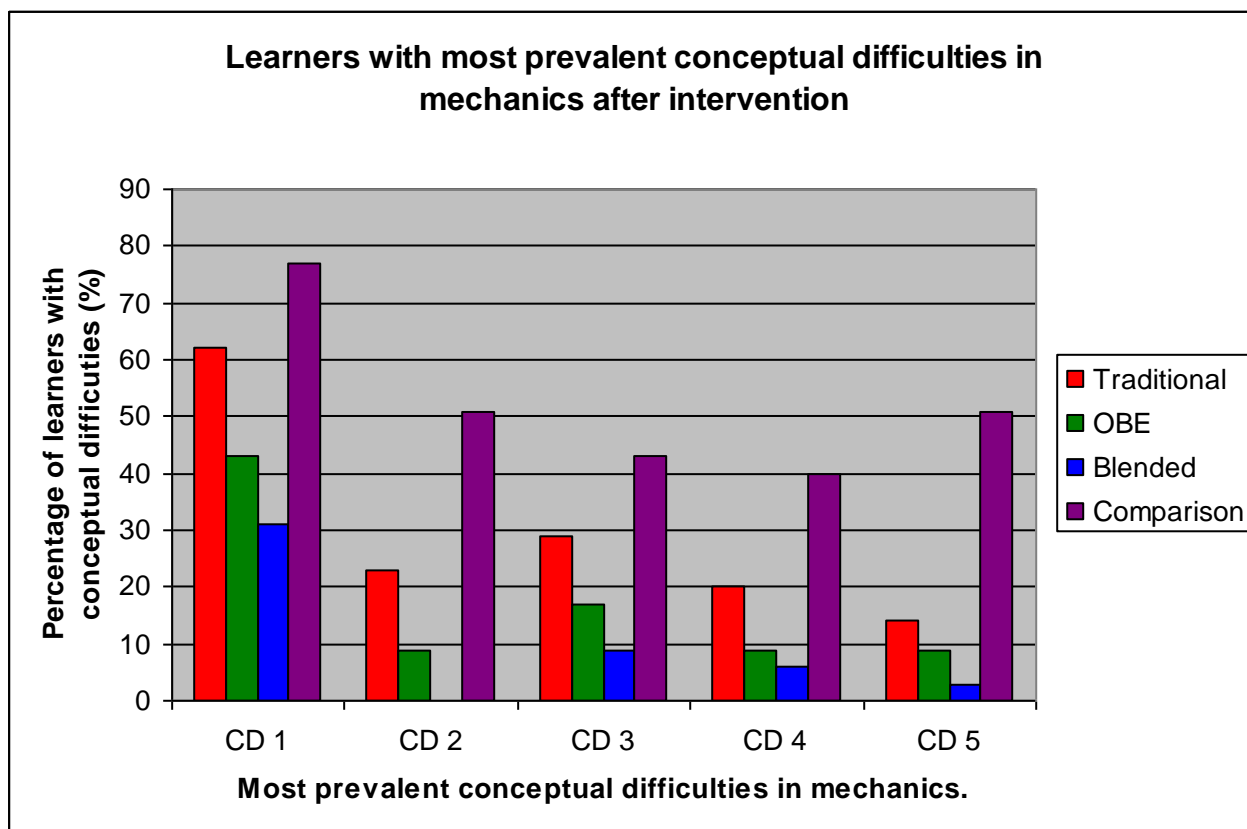
**Table 4.7: Most Prevalent Conceptual Difficulties (CD) (n = 140)**

Symbol	CONCEPTUAL DIFFICULTIES	Percentage of learners holding conceptual difficulties in mechanics after intervention (%)			
		Trad (35)	OBE (35)	Blend (35)	Comp (35)
CD1	<b>THEME: Motion on Incline Planes/Surfaces and Components of Vectors</b> Learners encounter a challenge in solving problems that involve resolving ' <i>the components of force or weight</i> '. This is more evident when solving problems that involve motion on incline planes/surfaces.	62 (89)	43 (86)	31 (77)	77 (86)
CD2	<b>THEME: Work Concept</b> To learners, ' <i>work</i> ' is simply the product of force and displacement, that is, $W = F \cdot \Delta x$ . The issue of ' <i>the component of the force</i> ' is disregarded by learners. Thus, they cannot distinguish between ' <i>positive work</i> ' and ' <i>negative work</i> ' as well as ' <i>no work done</i> '.	23 (63)	9 (51)	0 (43)	51 (49)
CD3	<b>THEME: Work-Energy Theorem (Application)</b> Learners fairly understand work-energy theorem. This is evident when they are required to apply the theorem.	29 (54)	17 (49)	9 (37)	43 (51)
CD4	<b>THEME: Kinetic Energy</b> In the kinetic energy formula, $K = \frac{1}{2} mv^2$ , learners are unable to recognize the relationship between mass and kinetic energy, and between velocity and kinetic energy.	20 (49)	9 (51)	6 (54)	40 (49)

CD5	<b>THEME: Principle of Conservation of Mechanical Energy</b> Learners fairly understand the Principle of Conservation of Mechanical Energy. This is evident when they apply the principle. Learners do not clearly understand the following concepts that relate to the principle: <i>'system', 'isolated or closed system', 'conservation', internal forces, external forces and so on.</i>	14 (63)	9 (49)	3 (54)	51 (57)
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From Table 4.7 there were higher percentages of learners in the traditional group followed by OBE group, still with the conceptual difficulties even after the intervention. The conceptual difficulty number two (CD2) was completely overcome by the blended teaching and learning strategy or approach followed by CD5 which was almost completely overcome as well.

Figure 4.43 summarises the values in Table 4.15. The traditional group is indicated as **red**, OBE group as **green**, the blended group as **blue** and the comparison group as **purple**.



**Figure 4.43 Most Prevalent Conceptual Difficulties after Intervention**

Figure 4.43 Compares the frequencies of identified most prevalent conceptual difficulties among the Traditional, OBE, Blended and the Comparison Groups after Interventions. Some conceptual difficulties were persistent and some were almost completely alleviated in the blended group followed by the OBE group. The conceptual difficulty number 2 was completely overcome in the blended group. With regard to the comparison group, there was almost no conceptual change. A number of learners were still holding conceptual difficulties in the traditional group.

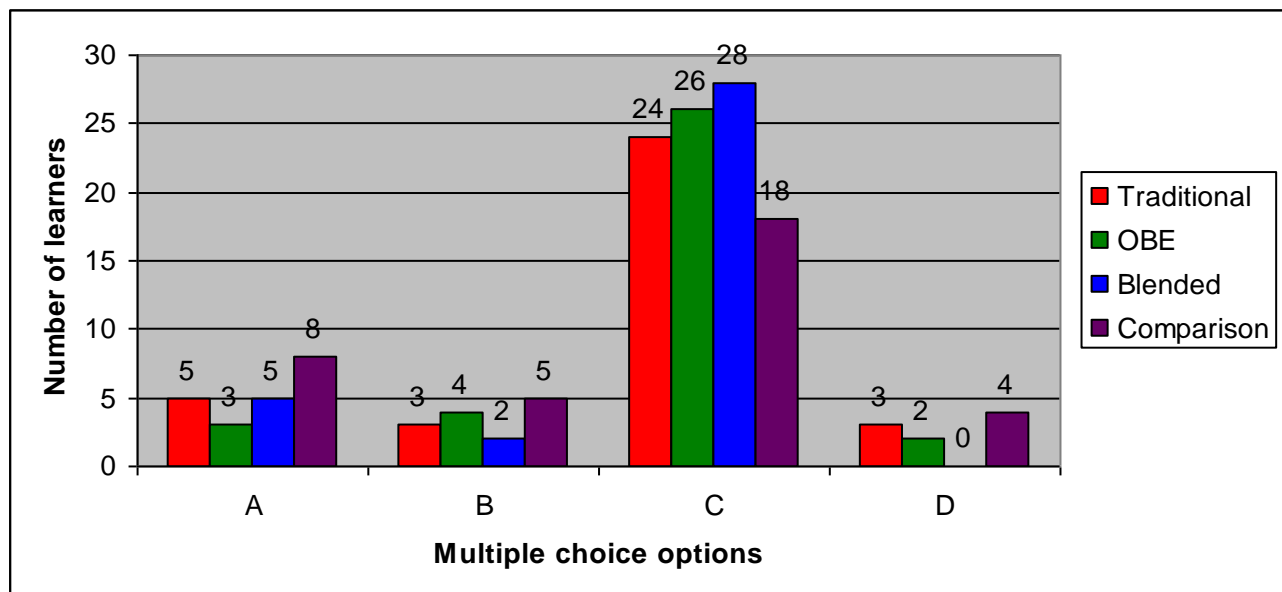
Figure 4.43 also shows that there was a significant difference in the effectiveness of the three interventions. The percentage for the first prevalent conceptual difficulty (CD1) was the highest among the three intervention

groups, as well as in the comparison group. This implies that CD1 (**Motion on Inclined Planes/Surfaces and Components of Vectors**) was resistant to change even after the intervention.

#### 4.5.6 Quantitative and Qualitative Analysis of Post-test for Alternative Conceptions in Mechanics

Figures 4.44 to 4.53 show the graphs of the number of learners from the experimental groups (traditional, OBE and blended) as well as the comparison group, who chose options A, B, C and D in the Basic Mechanics Test (BMT) for post-test. However, for each group a number of alternative conceptions still persisted even after the intervention. Some of the alternative conceptions identified were resistant to change. Again, each figure below reflects that there was no significant change in comparison group for post-test.

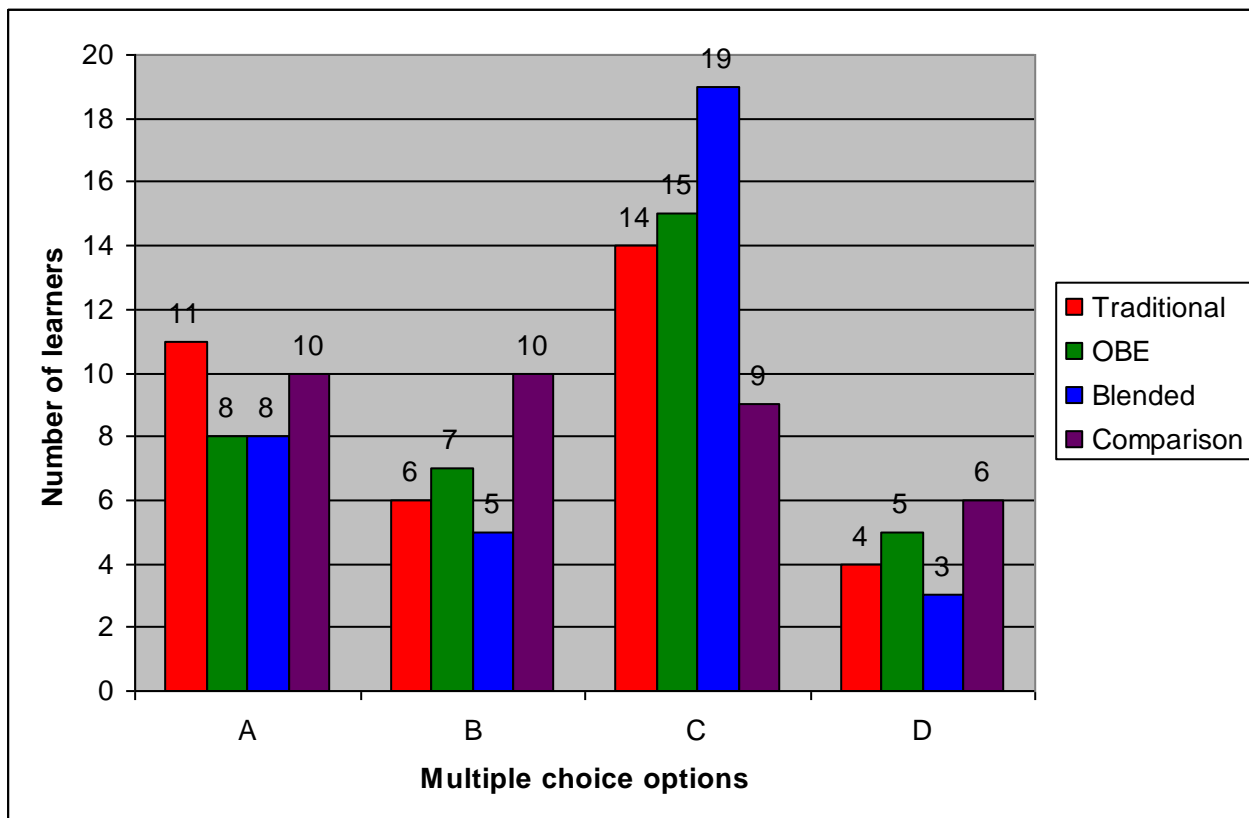
#### QUESTION 16



**Figure 4.44 Number of Learners who selected the intended Response from the four groups**

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some learners still held an alternative conception with regard to projectile motion, particularly concerning acceleration of a projectile. From the intended option, there were 28, 26, 24 and 18 learners from the blended, OBE, blended and comparison group respectively.

### QUESTION 17



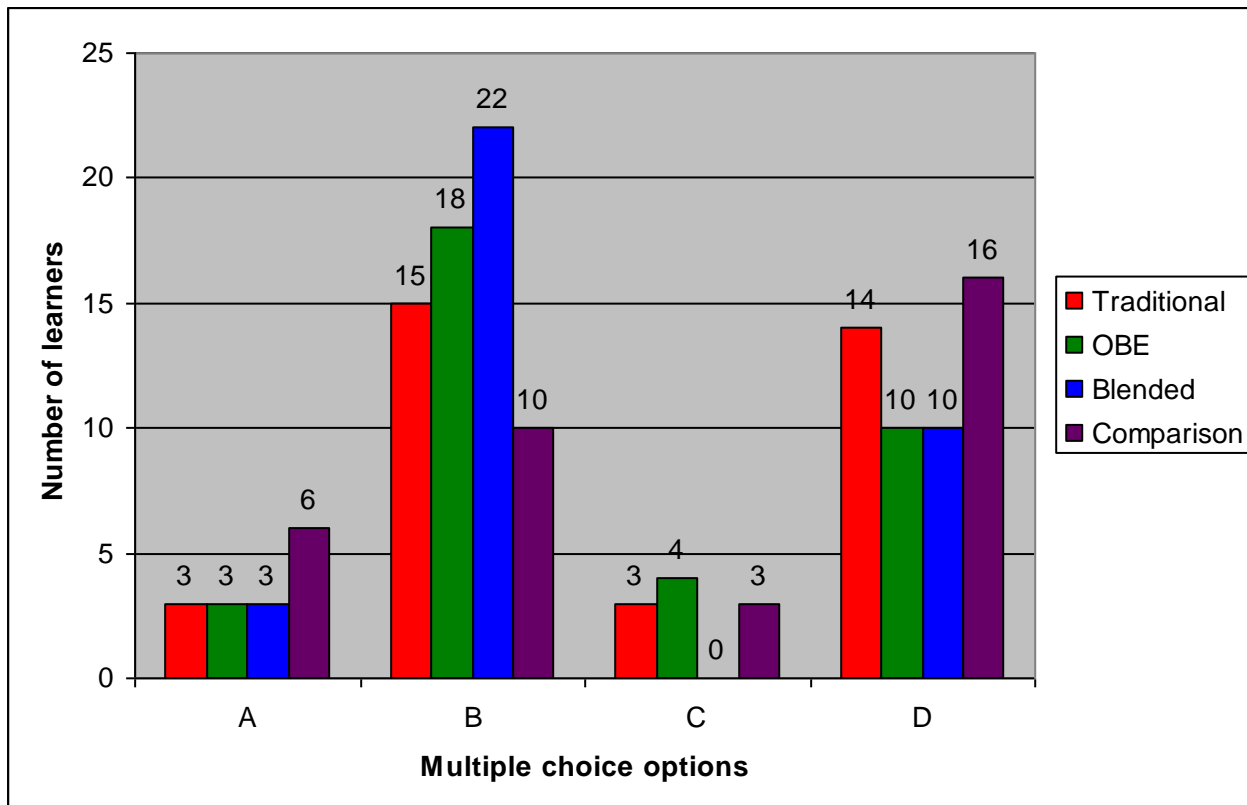
**Figure 4.45 Number of Learners who selected the intended Response from the four groups**

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some

learners still demonstrated an alternative conception with regard to projectile motion, particularly concerning velocity and acceleration of a projectile.

Figure 4.45 shows that the number of learners who selected the correct option was 19 for the blended group, 15 for the OBE group, 14 for the traditional group and 9 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### QUESTION 18



**Figure 4.46 Number of Learners who selected the intended Response from the four groups**

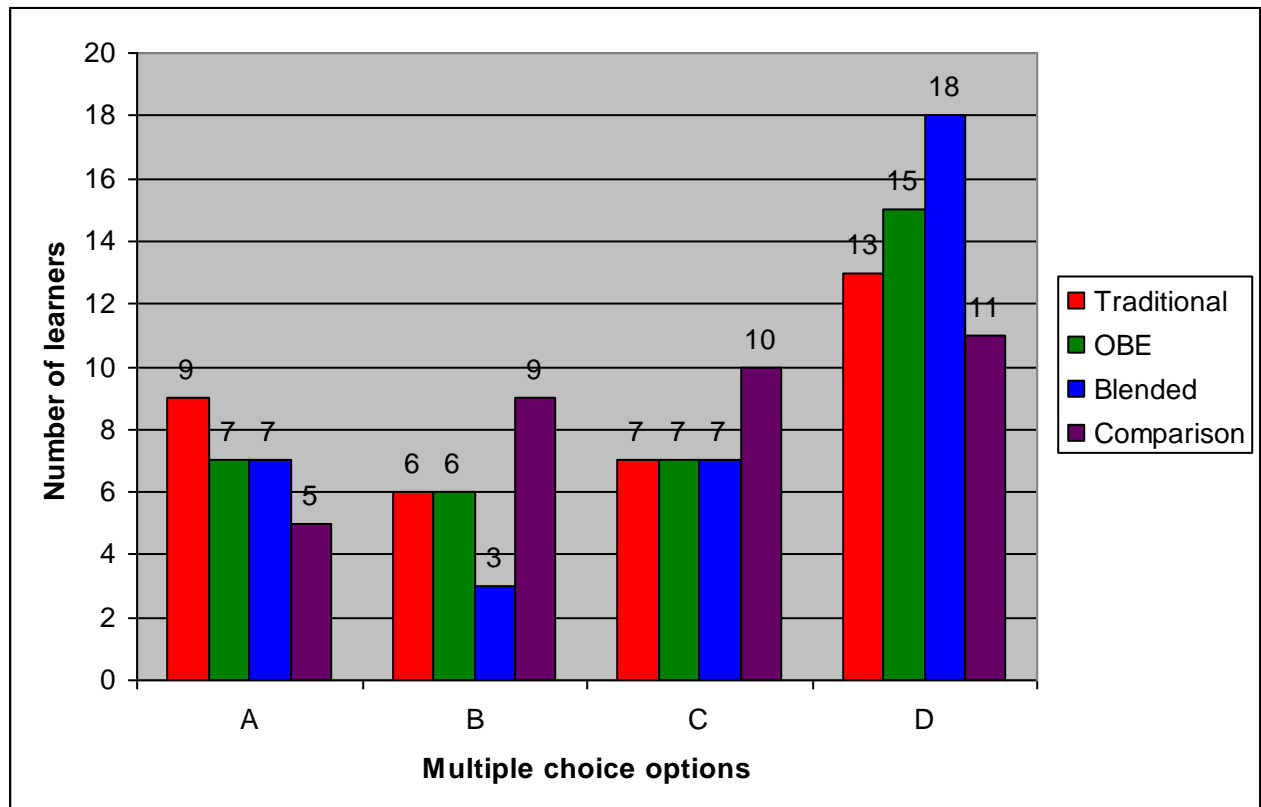
Option B was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some



learners still demonstrated an alternative conception with regard to projectile motion, particularly interpreting the velocity graphs of motion.

Figure 4.46 shows that the number of learners who selected the correct option was 22 for the blended group, 18 for the OBE group, 15 for the traditional group and 10 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### QUESTION 19



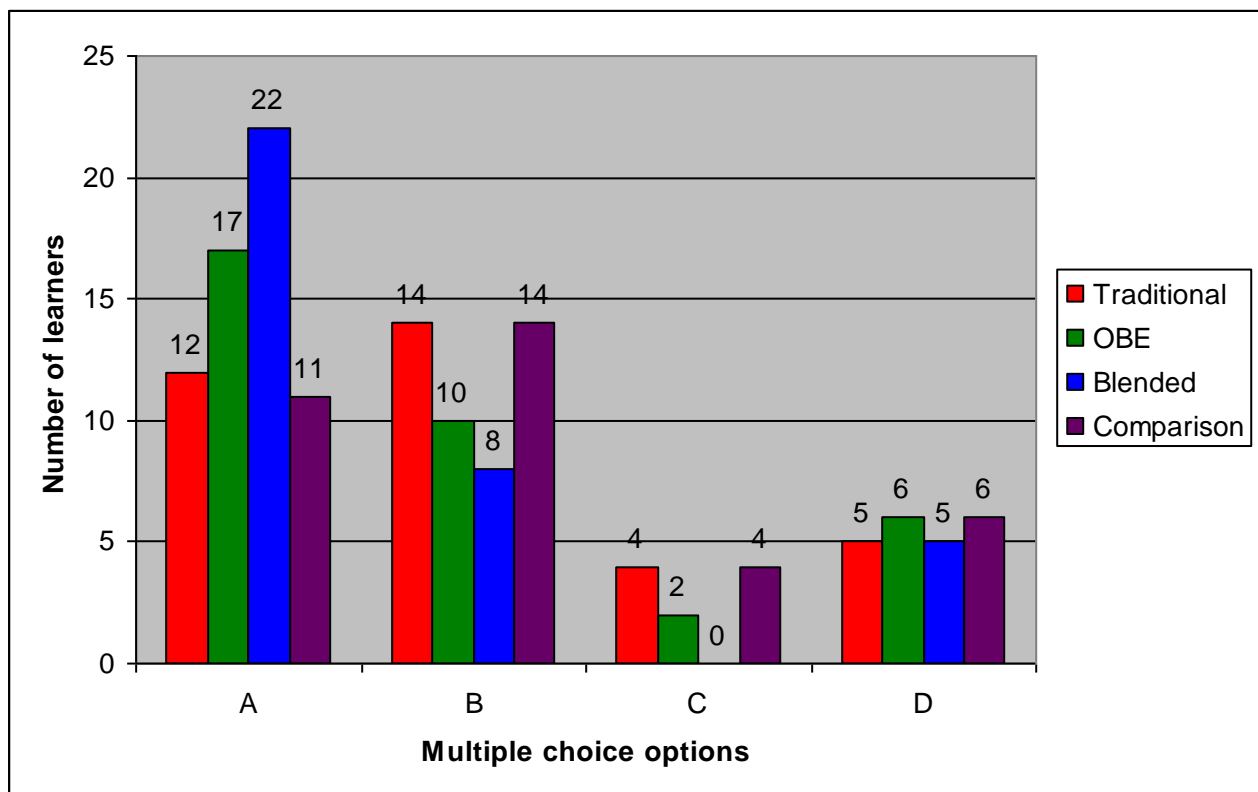
**Figure 4.47 Number of Learners who selected the intended Response from the four groups**

Option D was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some

learners still displayed an alternative conception with regard to projectile motion, particularly speed and velocity as different physical quantities, that is, scalar and vector nature of the quantities.

Figure 4.47 shows that the number of learners who selected the correct option was 18 for the blended group, 15 for the OBE group, 13 for the traditional group and 11 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### QUESTION 20

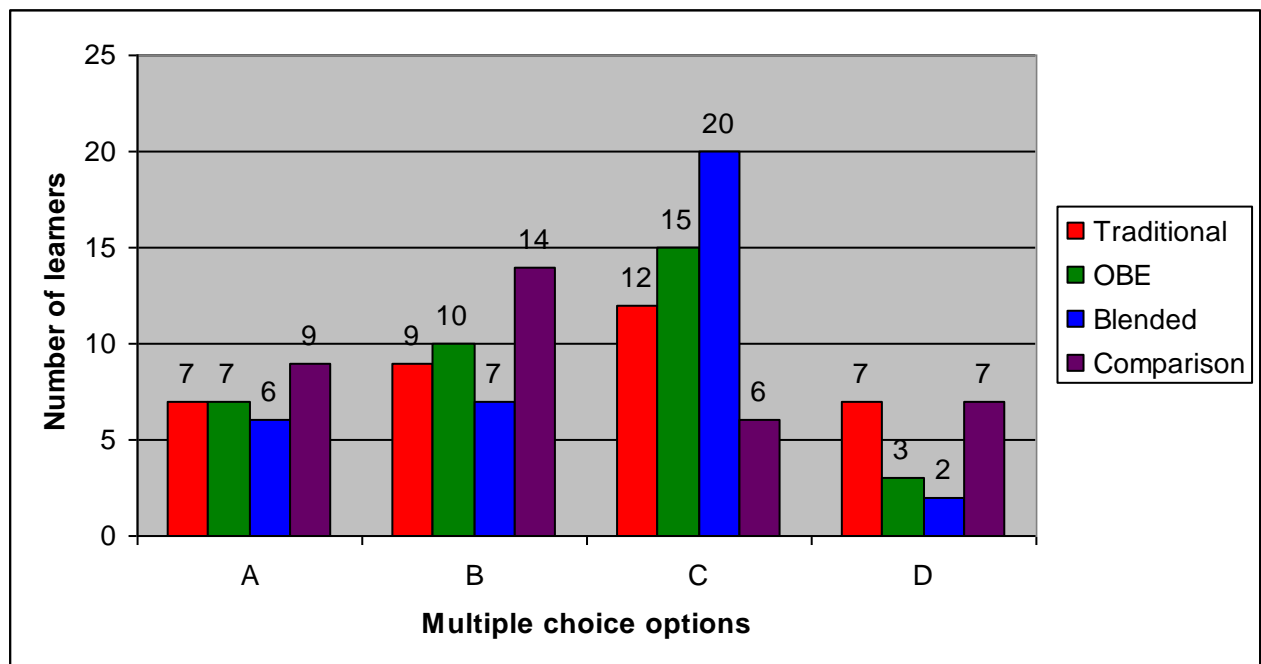


**Figure 4.48** Number of Learners who selected the intended Response from the four groups

Option A was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some learners still demonstrated an alternative conception with regard to projectile motion, particularly kinetic energy graphs, that is, changes in kinetic energy for projectile motion.

Figure 4.48 shows that the number of learners who selected the correct option was 22 for the blended group, 17 for the OBE group, 12 for the traditional group and 11 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

#### QUESTION 21

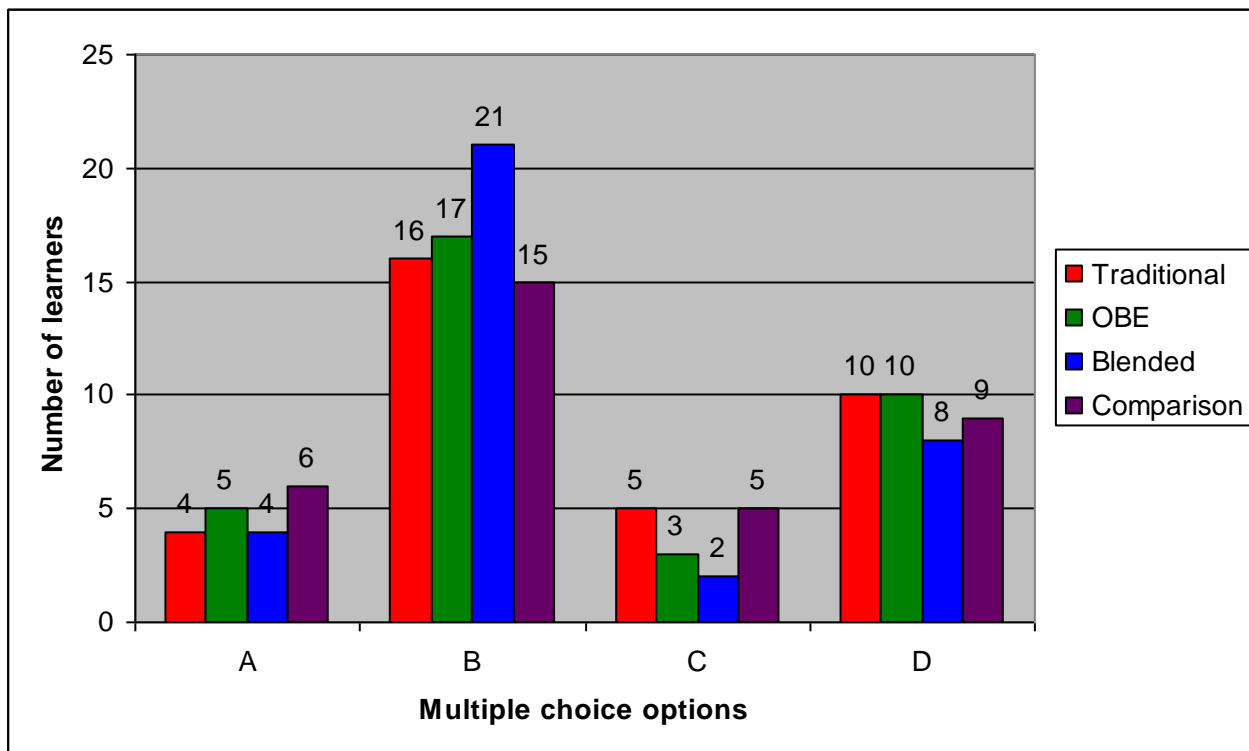


**Figure 4.49 Number of Learners who selected the intended Response from the four groups**

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some learners still demonstrated an alternative conception with regard to the concept of force particularly force and the motion of objects.

Figure 4.49 shows that the number of learners who selected the correct option was 20 for the blended group, 15 for the OBE group, 12 for the traditional group and 6 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

## QUESTION 22

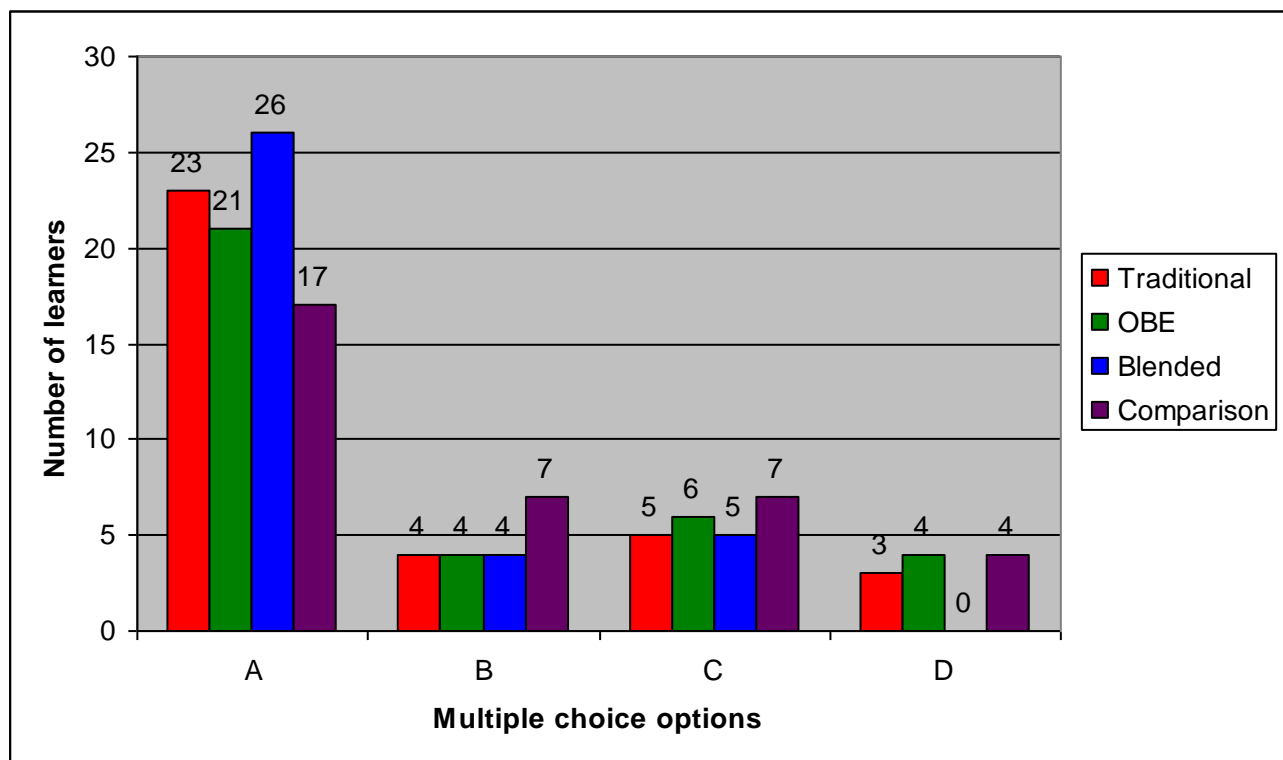


**Figure 4.50** Number of Learners who selected the intended Response from the four groups

Option B was the intended option and was also a majority option, with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some learners still displayed an alternative conception with regard to Newton's Third Law of motion particularly action-reaction force pairs.

Figure 4.50 shows that the number of learners who selected the correct option was 21 for the blended group, 17 for the OBE group, 16 for the traditional group and 15 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE group.

### QUESTION 23

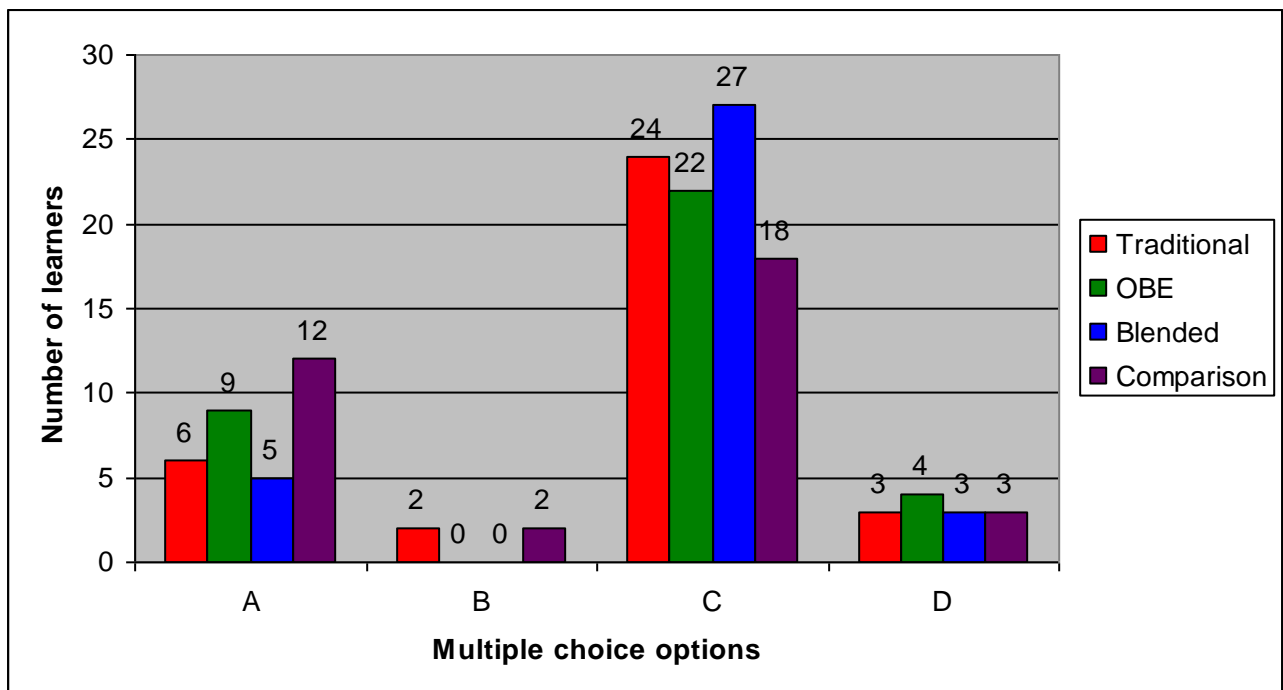


**Figure 4.51 Number of Learners who selected the intended Response from the four groups**

Option A was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some learners still held an alternative conception with regard to the concept of force particularly, force and static objects.

Figure 4.51 shows that the number of learners who selected the correct option was 26 for the blended group, 21 for the OBE group, 23 for the traditional group and 17 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the traditional group.

#### QUESTION 24

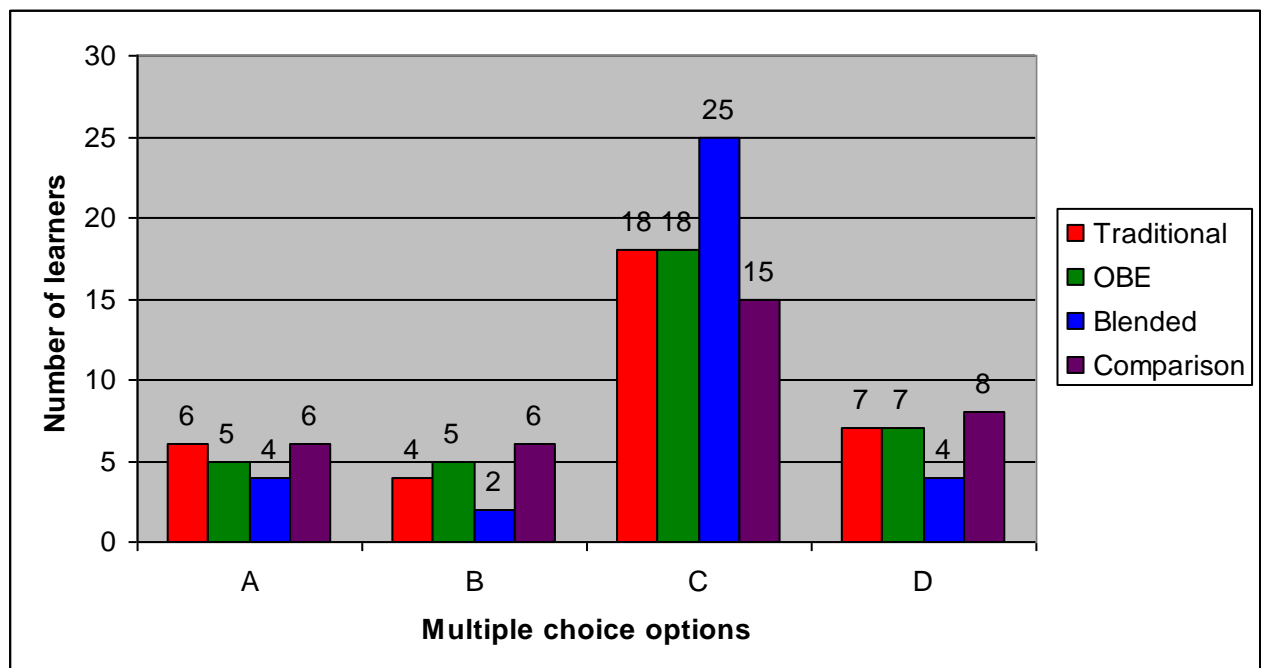


**Figure 4.52** Number of Learners who selected the intended Response from the four groups

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some learners still displayed an alternative conception with regard to the concept of force particularly active force as relating to Newton's Third Law of motion.

Figure 4.52 shows that the number of learners who selected the correct option was 27 for the blended group, 22 for the OBE group, 24 for the traditional group and 18 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the traditional group.

### QUESTION 25



**Figure 4.53** Number of Learners who selected the intended Response from the four groups

Option C was the intended option and was also a majority option with the blended group leading in terms of the number of learners who chose the intended option. However, some alternative conceptions still persisted. Some learners still demonstrated an alternative conception with regard to weight/mass concepts as related to force applied to an object.

Figure 4.53 shows that the number of learners who selected the correct option was 25 for the blended group, 18 for the OBE group, 18 for the traditional group and 15 for the comparison group. Among the intervention groups, the blended group had the highest number of learners who selected the intended option followed by the OBE and traditional groups with same number of learners who selected the intended option.

#### **4.5.7 Alleviation of Alternative Conceptions**

The frequency of the identified most prevalent alternative conceptions were determined following the traditional, OBE, the blended interventions as well as the comparison group. The effectiveness of the interventions in overcoming or alleviating the alternative conceptions was compared.

Table 4.8 summarises the frequencies of learners in each group, for each alternative conception. The traditional group is indicated in **red**, OBE group as **green**, the blended group in **blue** and comparison group in **purple**. The original percentages before the interventions (i.e. Table 4.6) are indicated in brackets to enable easy comparison.

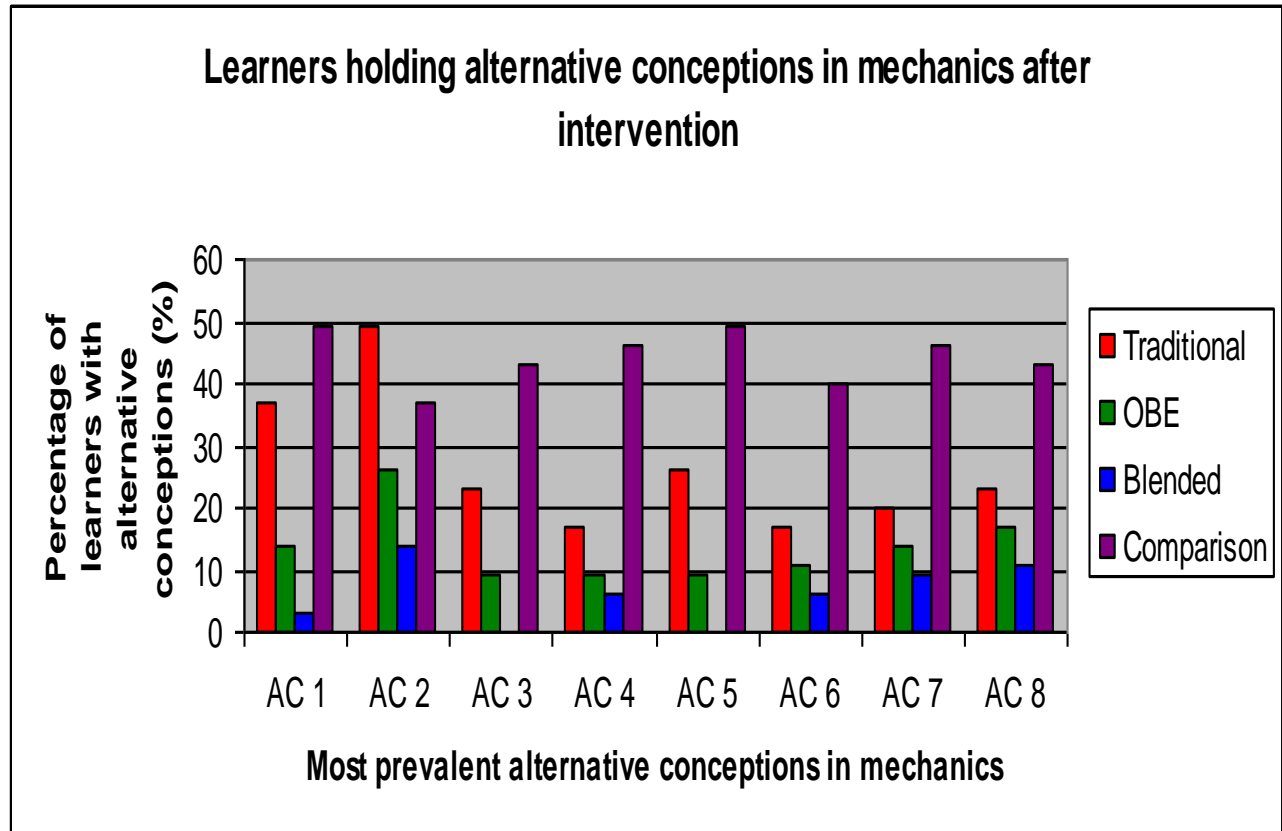


**Table 4.8: Most Prevalent Alternative Conceptions**

Symbol	ALTERNATIVE CONCEPTION	Learners holding ACs after intervention			
		Trad (35)	OBE (35)	Blend (35)	Comp (35)
AC1	<b>THEME: The Velocity and Acceleration of Projectiles</b> The velocity and acceleration of a projectile increase as it goes up.	37 (49)	14 (40)	3 (46)	49 (51)
AC2	<b>THEME: Weight / Mass of an Object</b> The weight, or mass, of an object has an effect on the magnitude of the force it exerts.	49 (43)	26 (51)	14 (37)	37 (46)
AC3	<b>THEME: Force Concept</b> Force is needed to keep an object moving at all times.	23 (54)	9 (51)	0 (43)	43 (40)
AC4	<b>THEME: Objects in Motion</b> Only active agents exert forces	17 (40)	9 (43)	6 (51)	46 (54)
AC5	<b>THEME: Static Objects</b> Objects that are not moving do not exert forces.	26 (57)	9 (60)	0 (54)	49 (49)
AC6	<b>THEME: Newton's Third Law</b> Action-reaction forces occur at different times.	17 (54)	11 (46)	6 (49)	40 (51)
AC7	<b>THEME: Acceleration of the projectiles</b> At the highest point, the projectile has zero acceleration.	20 (57)	14 (51)	9 (46)	46 (49)
AC8	<b>THEME: Active Force</b> Motion implies active force.	23 (49)	17 (46)	11 (51)	43 (54)

Table 4.8 indicates five most prevalent alternative conceptions that emanated from the learners BMT responses. From Table 4.8 there were also higher percentages of learners in the traditional group followed by OBE group, still with the alternative conceptions even after the intervention. The alternative conceptions numbers three and five (AC3 & AC5) were completely overcome by the blended teaching and learning strategy or approach followed by AC1

which was almost completely overcome as well. The traditional group is indicated in **red**, OBE group in **green**, the blended group in **blue** and the comparison group in **purple**. Figure 4.54 illustrates the information in Table 4.8.



**Figure 4.54 Most Prevalent Alternative Conceptions after Intervention**

Figure 4.54 Compares the Frequencies of Identified Most Prevalent Alternative Conceptions among the Traditional, OBE, Blended and Comparison Groups after Interventions. There were eight alternative conceptions that were identified in mechanics. The alternative conceptions number 3 and 5 were completely alleviated from the blended group. Some alternative conceptions were resistant to change, more particularly, from the traditional and OBE intervention groups. With regard to the comparison group there was almost no

conceptual change. Table 4.54 indicate the frequencies of the most alternative conceptions in percentage.

Figure 4.54 also shows that there was a significant difference among the effectiveness of the three interventions. Regarding the experimental groups, the frequencies indicated as percentage for the traditional group were higher than that of the OBE and the blended groups for the learners holding the alternative conceptions after the interventions. This implies that the traditional approach had the least effect on the alleviation of the alternative conceptions in mechanis. Figure 4.54 indicates that AC 3 and AC 5 for the blended group were completely overcome. Other alternative conceptions were resistant to change. With regard to the comparison group, there was almost no change as compared to the frequencies of the pre-test. The frequencies for the comparison group were still above 40% for each alternative conception.

## 4.6 EFFECTIVENESS OF INTERVENTIONS

**The effectiveness of the interventions developed and implemented, was ascertained in line with the following hypotheses:**

- An intervention based on the traditional instructional approach has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- An OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.
- A Blended instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions in mechanics.
- There is no statistically significant difference amongst OBE-based, traditional and blended instructional interventions in alleviating the

conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.

#### **4.6.1 The Analysis of Variance**

The pre-test scores of the learners on the TBM were compared in the four groups using One Way Analysis of Variance (ANOVA). BMA informa healthcare states that “ANOVA is perhaps the most powerful statistical tool. ANOVA is a general method of analysing data from designed experiments (experiments with a particular structure), whose objective is to compare two or more group means. Typically, however, the one-way ANOVA is used to test for differences among at least three groups, since the two groups can be covered by a t-test. This was done to ascertain the initial equivalence of the four groups.

Wikipedia, free encyclopedia, also maintains that

In statistics, ANOVA is a collection of statistical models, and their associate procedures, in which the observed variance in a particular variable is partitioned into components due to different sources of variation. In its simplest form ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalises t-test to more than two groups.

Table 4.9 presents the mean scores of the four groups in the pre-test, including the comparison group.

**Table 4.9 Comparisons of the means of the Traditional, OBE, Blended and Comparison Groups on the Pre-Test**

Group	N	Means
Traditional Pre-test	35	48,43
OBE Pre-test	35	48,74
Blended Pre-test	35	49,31
Comparison Pre-test	35	49,71
<b>The average of means</b>	<b>35</b>	<b>49,05</b>

Table 4.9 shows the means of all the four groups, that is, traditional (48,43), OBE (48,74), blended (49,31) and comparison (49,71) group involved in the study. The pre-test scores for the four groups were statistically compared for equivalence. The result is presented in Table 4.10.

**Table 4.10: Summary of the statistical difference among the four groups on the BMT at the onset of the study**

Source	SS	Df	MS	F <sub>o</sub>	F <sub>c</sub>	Result
Between	34,43	3	11,48	0,17	2,68	p>0,05 not significant
Within	9399,94	136	69,12			
Total	9434,37	139				

The result shown in Table 4.10 indicates a non-significant difference in the pre-test scores of learners in the four groups. The critical F<sub>c</sub> is greater than the observed F<sub>o</sub> hence,  $p > 0,05$ . This result shows that the groups were equivalent at the onset of the study, with regard to their pre-test scores. The result provides the basis to assume that any differences subsequently observed in the learners' scores, after the instructional interventions, could be attributed to the respective instructional interventions.

**Hypothesis 1:** An intervention based on the traditional instructional approach has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.

This hypothesis aimed to examine the effectiveness of the traditional approach to teaching and learning in improving Grade 12 physical science learners' performance. The pre- and post-test scores for this group of learners were compared using the  $t$ -test statistic. The sample size,  $n$ , for each of the four groups was 35. Weigner (1993:240) suggests that "the  $t$  value ... is dependent on the sample size,  $n$ . As  $n$  increases, the  $t$  value approaches the  $z$  value for the same level of significance". Weigner (1993:240) further posits that "in practice, if the sample size exceeds 30 for any test of means hypothesis, then the  $z$  value can be used as a good approximation to the  $t$  value. If, however the sample is less than 30, then the  $t$  value must be used". Furthermore, Weigner (1993) gives the following summary in this regard:

- If the sample size is small (i.e. [ $n \leq 30$ ] or [ $n_1 + n_2 \leq 30$ ]), and the population standard deviation(s) is unknown: then always use the  $t$  statistic (with appropriate degree of freedom) instead of the  $z$  distribution.
- If the sample size is large (i.e. [ $n > 30$ ] or [both  $n_1$  and  $n_2$  exceed 30]), and the population standard deviation(s) is unknown: then the  $z$  statistic can be used as a good approximation to the  $t$  statistic with the sample standard deviation(s) being used as estimate(s) for the unknown population standard deviation(s) (Weigner, 1993:240).

The sample size for each group in this study was more than 30 and hence the  $z$ -test or  $z$  calculation was used instead of the  $t$ -test or  $t$  calculation. The result of this analysis is presented in Table 4.11. Each  $z$ -test or  $z$  calculation was then followed by One Way Analysis of Variance (ANOVA) tables for confirmation of the comparisons. The results are presented with reference to the hypothesis being tested.

**Table 4.11** *The z-test summary of the difference between pre-and post-test scores of learners exposed to the traditional intervention*

Group	N	Means	Sd	Df	z <sub>o</sub>	Result
Traditional Pre-test	35	48,43	5,29	68	-11,17	P < 0,05
Traditional Post-test	35	62,42	5,19			
<b>Δ (Change)/ difference in means</b>		13,99				

Table 4.11 presents the results showing a significant difference between the pre- and post-test scores for the traditional approach to teaching and learning. The traditional intervention pre-test mean was 48,43 (sd = 5,29) and the post-test mean for the traditional group was 62,42 (sd = 5,19);  $z(68) = -11,17$ ;  $p < 0,05$ . Therefore, there was a statistically significant difference between the pre-and the post-test results of the traditional group. This means that according to Table 4.19, the traditional intervention was effective in alleviating students' conceptual difficulties and alternative conceptions in mechanics. Table 4.12 shows One Way Analysis of Variance (ANOVA) for the same traditional group, done in order to certain the z- statistic test performed above.

**Table 4.12: Analysis of variance (ANOVA) of pre- and post-test scores of learners exposed to the traditional intervention.**

Source	SS	Df	MS	F <sub>o</sub>	F <sub>c</sub>	Result
Between	3425, 10	1	3425,10	94,721	3,98	P < 0,05
Within	2459,17	68	36,16			
Total	5884,27	69				

Table 4.12 presents the results showing a significant difference in the pre-test and post-test scores for the traditional approach to teaching and learning.

Therefore, there was a statistically significant difference ( $p < 0,05$ ) between the pre- and the post-test results of the traditional group. This is shown by  $F_o$  (94,721) observed that is greater than  $F_c$  (3,98) critical. The null hypothesis is therefore rejected in favour of the alternative, that is, that the traditional intervention was effective in alleviating students' conceptual difficulties and the alternative conceptions in mechanics.

**Hypothesis 2:** An OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by Grade 12 learners in mechanics.

This hypothesis examined whether or not there would be a significant difference in the learners' performance as a result of the exposure to the OBE approach to teaching and learning. The result of this approach was to determine the effectiveness of the OBE approach to teaching and learning in improving Grade 12 physical science learners' performance. The pre- and post-test scores for this group of learners were compared using the z-test statistic. The result of this analysis is presented in Table 4.13.

**Table 4.13** *The z-test summary of the difference between pre-and post-test scores of learners exposed to the OBE intervention*

Group	N	Means	Sd	Df	$z_o$	Result
OBE Pre-test	35	48,74	6,98	68	-12,98	$P < 0,05$
OBE Post-test	35	72,37	6,03			
<b><math>\Delta</math> (Change)/ difference in means</b>		23,63				



Table 4.13 presents the results showing a significant difference between the pre- and post-test scores for the OBE approach to teaching and learning. The OBE intervention pre-test mean was 48,74 (sd = 6,98) and the post-test mean for the OBE group was 72,37 (sd = 6,03);  $z(68) = -12,98$ ;  $p < 0,05$ . Therefore, there was a statistically significant difference between the pre-and the post-test results of the OBE group. This means that according to Table 4.14, the OBE intervention was effective in alleviating students' conceptual difficulties and alternative conceptions in mechanics. Table 4.14 shows ANOVA testing of the second hypothesis for the OBE group, as a way to confirming and cross-validating the above z- statistic result.

**Table 4.14: Analysis of variance (ANOVA) of pre- and post-test scores of learners exposed to the OBE intervention.**

Source	SS	Df	MS	F <sub>o</sub>	F <sub>c</sub>	Result
Between	9771,60	1	9771,60	163,63	3,98	P < 0,05
Within	4060,87	68	59,72			
Total	13832,46	69				

Table 4.14 presents the results showing a significant difference between the pre-test and post-test scores for the OBE approach to teaching and learning. Therefore, there was a statistically significant difference ( $p < 0,05$ ) between the pre- and the post-test results of the OBE group. This is shown by ( $F_o > F_c$ ), that is,  $F_o$  (163,63) that is greater than  $F_c$  (3,98). Thus, the null hypothesis rejected in favour of the alternative: that the OBE intervention was effective in alleviating the conceptual difficulties and alternative conceptions of the students in mechanics.

**Hypothesis 3:** A Blended instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions in mechanics.

This hypothesis aimed to examine the effectiveness of the blended approach to teaching and learning in improving Grade 12 physical science learners' performance. The pre- and post-test scores for this group of learners were compared using the z-test statistic. The result of this analysis is presented in Table 4.15.

**Table 4.15** *The z-test summary of the difference between pre-and post-test scores of learners exposed to the blended intervention*

Group	N	Means	Sd	Df	z <sub>o</sub>	Result
Blended Pre-test	35	49,31	9,52	68	-17,69	P < 0,05
Blended Post-test	35	94,28	11,52			
<b>Δ (Change)/ difference in means</b>		44,97				

Table 4.15 presents the results showing a significant difference between the pre- and post-test scores for the blended approach to teaching and learning. The blended intervention pre-test mean was 49,31 (sd = 9,52) and the post-test mean for the blended group was 94,28 (sd = 11,52);  $z(68) = -17,69$ ;  $p < 0,05$ . Therefore, there was a statistically significant difference between the pre-and the post-test results of the blende group. This means that the blended intervention was effective in alleviating the conceptual difficulties and alternative conceptions of the students in mechanics. Table 4.16 shows the ANOVA results on the same group, done to cross-validate the above z- statistic result.

**Table 4.16: Analysis of variance (ANOVA) of pre- and post-test scores of learners exposed to the blended intervention.**

Source	SS	Df	MS	F <sub>o</sub>	F <sub>c</sub>	Result
Between	35390,27	1	35390,27	307,87	3,98	P < 0,05
Within	7816,68	68	114,95			
Total	43206,96	69				

Table 4.16 presents the results showing a significant difference between the pre-test and post-test scores for the blended approach to teaching and learning. The critical F is less than the observed F ( $F_c < F_o$ ). Therefore, there was a statistically significant difference ( $p < 0,05$ ) between the pre- and the post-test results of the blended group. This means that the blended intervention was effective in alleviating students' conceptual difficulties and alternative conceptions in mechanics.

**Table 4.17 The z-test summary of the difference between pre-and post-test scores of learners for the comparison group**

Group	N	Means	Sd	Df	z <sub>o</sub>	Result
Comparison Pre-test	35	49,71	8,36	68	-0,43	P > 0,05
Comparison Post-test	35	50,74	11,26			
<b>Δ (Change)/ difference in means</b>		1.03				

Table 4.17 presents the results showing a non-significant difference in the pre- and post-test scores for the comparison group. There was no intervention that took place with this group. The comparison pre-test mean was 49,71 (sd = 8,38) and the post-test mean was 50,74 (sd = 11,26);  $z(68) = -0,43$ ;  $p > 0,05$ .

Therefore, there was no statistically significant difference between the pre-and the post-test results for the comparison group. Table 4.18 shows the ANOVA results on the same group, done to cross-validate the above z- statistic result.

**Table 4.18: Analysis of variance (ANOVA) of pre- and post-test scores of the comparison group.**

Source	SS	Df	MS	F <sub>o</sub>	F <sub>c</sub>	Result
Between	18,57	1	18,57	0,18	3,98	P > 0,05
Within	6875,83	68	101,12			
Total	6894,40	69				

Table 4.18 presents the results showing a non-significant difference in the pre-test and post-test scores for the comparison group. There was no intervention taking place with this group. Table 4.18 reflects that the critical F is greater than the observed F ( $F_c > F_o$ ). Therefore, there was no statistically significant difference ( $p > 0,05$ ) between the pre- and the post-test results for the comparison group. Hence, the null hypothesis was accepted that there is no significant difference in the pre- and post-test for the comparison group. The result provides the basis to assume that any differences subsequently observed in learners' gain scores, after exposure to teaching and learning strategies, could be due to the those teaching and learning strategies.

**Hypothesis 4:** There is no statistically significant difference amongst OBE-based, traditional and blended instructional interventions in alleviating the conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.

This hypothesis tested the differences in the extent of improvement in physical science learners' performance when they were taught using the traditional, OBE and blended approaches, respectively. The hypothesis was tested by comparing

the gain scores in the learners' performance following the traditional approach with the gain scores of learners' performance following the OBE approach and lastly with the gain scores of learners' performance following the blended approach. ANOVA was used for the analysis. The result of this analysis is summarised in Table 4.19.

**Table 4.19 Comparisons of the Traditional, OBE and Blended Groups on the Post-Test**

<b>Group</b>	<b>N</b>	<b>Means</b>	<b>Difference between trad &amp; OBE</b>	<b>Difference between OBE &amp; blended</b>	<b>Difference between trad &amp; blend</b>
Traditional Post-test	35	62,42	9,94		31,85
OBE Post-tests	35	72,37		21,91	
Blended Post-tests	35	94,28			

Table 4.19 shows the comparisons of the means of the post-tests of the traditional, OBE and blended (experimental) intervention groups. The means were 62,43; 72,37 and 94,28, respectively. The post-test mean for the blended group was the highest. The difference in means between the traditional and the OBE gorup was 9,94; between the OBE and the blended group was 21,91 and between the traditional and the blended group was 31,85.

**Table 4.20: ANOVA for the three intervention groups on the post-test**

Source	SS	Df	MS	$F_o$	$F_c$	Result
Between	531,37	2	265,69	5,84	3,09	$P < 0,05$
Within	4643,14	102	45,52			
Total	5174,51	104				

Table 4.20 indicates a significant difference in the post-test scores of the three groups (traditional, OBE and blended). The comparison group was not included in Table 4.20 since there was no significant difference between the pre- and post-test scores for the comparison group. Table 4.20 shows that the critical F is less than the observed F ( $F_c < F_o$ ). This means that there was a significant difference among the three groups, in their effectiveness in alleviating the conceptual difficulties and the alternative conceptions of the students in mechanics. Therefore, the existence of a significant difference in the post-test scores among the three groups led to the rejection of the hypothesis 4 of this study – given above. It was therefore necessary to conduct *a posteriori* comparisons among the three groups in order to establish where the significant differences lay. Thus, the following *a posteriori* statistical hypotheses were formulated, and are subsequently tested:

**Hypothesis 4.1:** There is no significant difference between the traditional and OBE-based instructional interventions in alleviating learning difficulties and alternative conceptions in mechanics.

**Hypothesis 4.2:** There is no significant difference between the traditional and blended instructional interventions in alleviating learning difficulties and alternative conceptions in mechanics.

**Hypothesis 4.3:** There is no significant difference between the OBE-based and blended instructional interventions in alleviating learning difficulties and alternative conceptions in mechanics. The tables that follow show the comparisons among the groups. Table 4.21 shows the comparison between traditional and OBE.

**Table 4.21** *Comparison of the Traditional and the OBE Group, on the Post-Test*

Group	N	Means	sd	Df	z <sub>o</sub>	Result
Traditional Post-test	35	62,42	5,19	68	-7,40	P < 0,05
OBE Post-test	35	72,37	6,03			
<b>Δ (Change)/ difference in means</b>		9,95				

Table 4.21 presents the results showing a significant difference in the post-test scores of the traditional and OBE groups. The traditional intervention post-test mean was 62,42 (sd = 5,19) and the post-test mean for the OBE group was 72,37 (sd = 6,03);  $z(68) = -7,40$ ;  $p < 0,05$ . Therefore, there was a statistically significant difference between the the post-test results of the traditional and OBE groups in favour of the OBE group. This means that the OBE intervention was more effective than the traditional approach in alleviating the conceptual difficulties and alternative conceptions of students in mechanics. Table 4.22 shows ANOVA between traditional and OBE group.

**Table 4.22: ANOVA results on the comparison between traditional and OBE groups**

Source	SS	Df	MS	F <sub>o</sub>	F <sub>c</sub>	Result
Between	1732,54	1	1732,54	53,15	3,98	P < 0,05
Within	2216,75	68	32,60			
Total	3949,29	69				

Table 4.22 presents the results similar to those presented in Table 4.21. As a way of cross-validating the results of the z- statistic, Table 4.22 shows that there was a significant difference between the traditional group vis-à-vis those of the OBE group ( $F_c < F_o$ ;  $p < 0,05$ ). Examination of the post-test mean scores shows that the statistical difference is in favour of the OBE-based intervention. **Thus, the answer to a *posteriori* statistical Hypothesis 4.1 is that an OBE-based instructional intervention is more effective in alleviating learning difficulties and alternative conceptions in mechanics than a traditional intervention.**

Table 4.23 shows the comparison between the traditional approach and blended groups.

**Table 4.23 Comparison of post-test scores of the traditional versus blended groups**

Group	N	Means	Sd	Df	t <sub>o</sub>	Result
Traditional Post-test	35	62,42	5.19	2 or 68	-14,9	P < 0,05
Blended Post-test	35	94,28	11,52			
<b>Δ (Change)/ difference in means</b>		31.86				



Table 4.23 presents the results showing a significant difference in the post-test scores of the traditional versus the blended intervention groups. The traditional intervention post-test mean was 62,42 (sd = 5,19) and the post-test mean for the blended group was 94,28 (sd = 11,52);  $z(68) = -14,9$ ;  $p < 0,05$ . Therefore, the statistically significant difference was in favour of the blended intervention group. This result is further cross-validated below through ANOVA. Table 4.24 shows ANOVA results on the comparison of the effectiveness of the traditional versus blended interventions.

**Table 4.24: (ANOVA) results on the comparison between traditional and blended interventions**

Source	SS	Df	MS	$F_o$	$F_c$	Result
Between	17763,54	1	17763,54	216,18	3,98	P < 0,05
Within	5587,71	68	82,17			
Total	23351,25	69				

Table 4.24 presents the results showing a significant difference ( $F_c < F_o$ ) and ( $p < 0,05$ ) between the traditional post-test scores and blended post-test scores. Examination of the mean scores of the two interventions shows that the statistical difference is in favour of the blended blended intervention. This confirms the results in Table 4.23. **Thus, the answer to a *posteriori* statistical Hypothesis 4.2 is that a blended instructional intervention is more effective in alleviating learning difficulties and alternative conceptions in mechanics than a traditional intervention.** Table 4.25 presents the results of the third and final comparison between the OBE and blended intervention groups.

**Table 4.25 Comparison of post-test scores of the OBE and blended groups**

Group	N	Means	sd	Df	z <sub>o</sub>	Result
OBE Post-test	35	72,37	6,03	68	-9,97	P < 0,05
Blended Post-test	35	94,28	11,52			
<b>Δ (Change)/ difference in means</b>		21,91				

The results in Table 4.25 show a significant difference between the post-test scores of the two groups. The OBE intervention post-test mean was 72,37 (sd = 6,03) and the post-test mean for the blended group was 94,28 (sd = 11,52);  $z(68) = -9,97$ ;  $p < 0,05$ . Therefore, there was a statistically significant difference between the post-test results of the OBE and blended groups, in favour of the latter. Table 4.26 presents ANOVA post-test score comparisons between the same two groups, for cross-validation purposes..

**Table 4.26: ANOVA comparisons between the OBE and blended intervention groups**

Source	SS	Df	MS	F <sub>o</sub>	F <sub>c</sub>	Result
Between	8400,84	1	8400,84	96,57	3,98	P < 0,05
Within	5915,31	68	86,98			
Total	14316,16	69				

Yet again, Table 4.26 presents consistent results with those presented in Table 4.25, that is, showing a significant difference ( $F_c < F_o$ ) and ( $p < 0,05$ ) between the OBE post-test and the blended post-test scores – again in favour of the the blended intervention group. Taken together, therefore, the significant differences

in the post-test scores of all the three groups lead to the rejection of the fourth hypothesis. This suggests that there is a statistically significant difference. Therefore, **the answer to a *posteriori* statistical Hypothesis 4.3 is that a blended instructional intervention is more effective in alleviating learning difficulties and alternative conceptions in mechanics than an OBE-based intervention.**

#### 4.6.2 The Average Normalised Gain Score (ANGS) Concept

The average normalised gain score concept was also used in this study to ascertain whether or not the effects of the treatments, that is, the three interventions (traditional, OBE and blended), fell in the *interactive-engagement zone*. Table 4.27 shows the three interventions with their pre- and post-test **mean scores**, as well as **ANGS percentages**. The actual calculations of the average normalised gain ( $g$ ) scores using the formula  $(g) = \% (G) / \% (G)_{\max} = [\% (S_f) - \% (S_i)] / [100 - (S_i)]$  are reflected in Appendix K. In the above formula,  $(S_f)$  and  $(S_i)$  are the final (post) and initial (pre) class averages that are calculated as percentages, hence  $\% (S_f)$  and  $\% (S_i)$ ;  $\% (G)$  represents the actual average gain expressed as  $[\% (S_f) - \% (S_i)]$ ; and  $\% (G)_{\max}$  represents the maximum possible average gain expressed as  $[100 - \% (S_i)]$ . The total marks of the BMT test was 129 marks. The percentage averages for pre-tests were computed as follows:

- Traditional group,  $\% (S_i) = \frac{48,43}{129} \times 100\% = 37,54\%$
- OBE group,  $\% (S_i) = \frac{48,74}{129} \times 100\% = 37,78\%$
- Blended group,  $\% (S_i) = \frac{49,31}{129} \times 100\% = 38,23\%$

- Comparison group,  $\%(S_i) = \frac{49,71}{129} \times 100\% = 38,53\%$

129

In the same way, the percentage averages for the post-tests were calculated using  $\%(S_f) = \text{mean score}/\text{total marks} \times 100\%$ , for each group.

**Table 4.27.** Comparisons of all the groups based on the ANGSC Concept ( $n = 140$ )

	<b>INTERVENTIONS/TREATMENTS AND COMPARISON GROUP</b>			
<b>Descriptions</b>	<b>Traditional</b>	<b>OBE</b>	<b>Blended</b>	<b>Comparison</b>
Total Marks	129	129	129	129
Pre-test Means	48,43	48,74	49,31	49,71
Post-test Means	62,42	72,37	94,28	50,74
$\%(S_i)$	37,54	37,78	38,23	38,53
$\%(S_f)$	48,39	56,10	73,09	39,33
$\%(S_f) - \%(S_i)$	10,85	18,32	34,86	0,8
$100 - \%(S_i)$	62,46	62,22	61,77	61,47
$(g) = \frac{[\%(S_f) - \%(S_i)]}{[100 - \%(S_i)]}$	0,17 ~ 0,20	0,29 ~ 0,30	0,56 ~ 0,60	0,01 ~ 0,00
<b>Average normalised gain (g)</b>	<b>0,20</b>	<b>0,30</b>	<b>0,60</b>	<b>0,00</b>

Table 4.27 shows the average normalised gain scores for the three interventions. The average normalised gains ( $g$ ) for the respective interventions were 0,20; 0,30 and 0,60. According to Hake (1997) ( $g$ ) is a much better indicator of the extent to which a treatment is effective. If the treatment yields ( $g$ )  $> 0,30$ , then the treatment could be considered as in the “interactive-engagement zone” (Hake, 1998; Meltzer, 2002). More specifically, “high gain” is defined as the one

with  $(g) = \geq 0,70$ ; “medium gain” with  $0,70 > (g) \geq 0,30$ ; and “low gain” with  $(g) < 0,30$  (Hake, 1998). The traditional intervention was not in the ‘interactive-engagement zone’. This means the interactive-engagement methods were poorly or not used at all. The OBE intervention was in the ‘interactive-engagement zone’. Table 4.27 shows medium gain,  $[(g) = 0,30]$  for the OBE group. This means the interactive-engagement methods (for example, group discussions) were fairly well used. The blended intervention was also in the medium gain  $[(g) = 0,60]$  which was the highest gain among the three interventions.

## 4.7 DISCUSSION OF FINDINGS

This section discusses the major findings of the study with brief reference to supporting literature. The discussion includes assessment preferences of the learners, teaching strategy preferences of the learners, learners’ responses on OBE, conceptual difficulties in mechanics, alternative conceptions, the effectiveness of the interventions.

This study reviewed a number of learning theories under literature review, with regard to learning, how a learner learns, and instructional strategies. Alonso, et, al (2005:222) posit that “learning begins with student engagement, which in turn leads to knowledge and understanding”. This study supported instructional strategies that encourage interactive engagement of learners. Hence, the blended approach to teaching and learning was determined to be the most effective teaching and learning approach. Regarding knowledge, Bruner (1986) believed that knowing is a process rather than the accumulated wisdom of science as presented in textbooks. Ausubel (1968) opines that the most single factor influencing learning is what the learner already knows. He further asserts that what the learner already knows should be ascertained so that the learner is taught accordingly (Ausubel, 1986). To ascertain what the learner already know helps to identify the preconceptions, conceptual difficulties experienced by

learners and alternative conceptions held by the learners. Ausubel's (1968) argument is mainly based on meaningful learning in which knowledge is related by the learner to relevant existing concepts in that of learner's structure. His assimilation theory of meaningful learning stresses the importance of prior knowledge in learning new concepts.

With regard to instructional strategies, Gagne` believed that effective instruction should reach beyond traditional learning theories (Killpatrick, 2001). According to Gagne` instruction should be designed to include a variety of instructional methods in order to meet the needs of different learners (Killpatrick, 2001). Three interventions are used in this study of which blended approach is one of them. In line with Gagne`'s learning theory, blended approach is an approach that mixes different learning delivery modes (Singh & Reed, 2001) to meet the needs of different learners. The blended approach to teaching and learning is therefore supported by Gagne`'s theory of learning.

This study was therefore supported by both behaviourist and constructivist theories of learning. Behaviourists believe that behaviours of learners can be controlled and best served through direct, whole class, lecture and demonstration instructional strategies (Reddy, Ankiewicz & Swardt, 2005). Constructivist theory maintains that learners construct or at least interpret their own reality based on their perception of experience. Hence, Geer and Rudge (2002) describe constructivism as a theory of learning where students construct knowledge in the process of learning through social interaction and active participation with the phenomena, as they develop shared-meanings of the phenomena. Learners are therefore not seen as passively receiving knowledge from the environment.

Connectivism, the learning theory for the digital age, which recognises the input of technology (Siemens, 2004) was also reviewed. Avraamidou (2008:350) reports that

technology tools have reshaped the way teaching and learning is viewed during the past few years as they provide access to information, the means to engage and manipulate resources and the opportunities for communication of ideas and collaboration at both individual and institutional level.

The blended approach used in this study used a variety instructional strategies including computer-mediated learning. Dubendorf (2003) report that researchers have argued that technologies have the potential to improve efficiency and effectiveness in teaching and learning. Technologies also challenge the essence of face-to-face teaching and learning (Kukulska-Hulme, 2005). Among the traditional, OBE and blended approach, blended approach was found to be the most effective approach to teaching and learning.

This study also reviewed and applied the activity theory (AT) with regard to the three instructional approaches. It was determined that AT is used to develop an understanding of complex roles and relationships that concerns education (Bakhurst, 2009; Beauchamp, Jazvac-Martek & McAlpine, 2009). AT is viewed as a potentially fertile paradigm for research in education (Bakhurst, 2009). AT focuses on the achievement of long-term goal – outcome – through mediational means of tools such as language, concepts or signs, within a community governed by rules and division of labour (Engestrom, 1987). It also focuses on human activity and work practices and an activity consists of a subject, mediated by a tool (Uden, 2007).

Generally, with regard to this study as related to AT, a learner was a common subject for all intervention groups. Educator and learners together formed a community that was governed by the classroom rules as well as tests, assignment instructions (for learners). The object was the achievement of the learning outcomes through tests, assignment, and homework. Alleviation of conceptual difficulties and alternative conceptions in mechanics was the ultimate

outcome. Regarding the division of labour, educator ensured that teaching and learning was effective and was also responsible for facilitation, providing input where necessary and giving of feedback to learners. Learners were to follow instructions, write tests and submit assignment. There were many activity systems during interventions.

#### **4.7.1 Assessment Preferences of Learners**

Learners were given to choose the assessment method they preferred educators to use when assessing them. There were 71 (51%) learners who preferred to be assessed through the use of both the Continuous Assessment (CA) and Tests and Examinations (T & E). This was the majority response of the learners, followed by learners (47%) who preferred only the CA. With regard to learners who preferred to be assessed through Continuous Assessment only, the research by Coetzee (2008) agrees with the findings mentioned above in that on average about half a sample of learners also preferred to be assessed through CA. However, with regard to assessment through T & E only, this study revealed that 03 (02%) preferred T & E, whereas the study by Coetzee (2008) reflects that more students (56%) preferred T & E. Thus the majority of the learners support the current method of assessment that is practised in South Africa, especially in Senior Phase classes and in the FET band. According to the Department of Education (2005) CA bases decisions about learning on a range of different assessment activities and events that happen at different times throughout the learning process. More specifically, CA involves assessment activities that are spread throughout the year, using various kinds of assessment methods such as tests, examinations, projects and assignments, to name but a few.



#### 4.7.2 Teaching Strategies Preferences of Learners

Learners were also afforded an opportunity to indicate the teaching strategies they preferred. In response, 43 (31%) learners preferred to be taught through group work, 38 (27%) preferred to be taught through practical work or practical investigations, 35 (25%) preferred the OBE approach and relatively fewer learners 07 (05%) preferred lecturing. These findings did not agree with the findings by Coetzee (2008) preferred instructional strategies. Coetzee (2008) found that lecturing was the most favourite instructional mode preference and OBE instructional approach was rated the least.

This study revealed that learners preferred group work the most and rated self-study and lecturing the least. Learners preferred learning through communication and sharing of ideas. The interactive engagement worked best for them. This was evident through the OBE and blended groups. The main pedagogical attributes of OBE, according to Imenda (2002:13), to name but a few, are (1) learners should be assessed on an on-going basis and (2) learning should be learner-centred, teacher to function as facilitator (use of group work and other active learning approaches emphasised).

The ability to work effectively in groups is one of the critical outcomes of OBE. Group work involves looking for evidence that the group of learners co-operate, assist one another, divide work, and combine individual contributions into a single composite assessable product. *Group assessment* looks at process as well as product. It involves assessing social skills, time management, resource management and group dynamics, as well as the output of the group (Airasian, 1994:17; OBE assessment, 2001:29).

There are some activities which are better done in groups like the following: Presentations, discussions, problem solving, project work, field trips, sharing ideas, etc. (Department of Education, 2003:17). Other than when a group

assesses a learner, group assessment can also be used by an educator to assess the entire group (Airasa, 1994:17; Department of Education, 2001:29). Droogan and Houson (2011) maintain that groupwork is very worthwhile, in particular for the less able students, as the more able students are able to explain the idea behind the concept involved. Groupwork also leads to further interesting questions which the students can propose.

#### **4.7.3 Learners' Responses on OBE**

The BMT allowed learners to voice out views with regard to OBE. Learners' responses were categorised into two strands, that is, (1) learners' comments *in favour* of OBE, and (2) learners' comments that were *not in favour* of OBE. The following were the learners' comments in favour of OBE and comments not in favour of OBE:

Learners' comments in favour (positive comments) of OBE:

*"I think OBE was the best technique because in nowadays you get that the class is full of 60 up to 68 learners so obvious the teacher won't be able to get time to make all these learners to understand but if they are in groups it is more easy to make them understand. And also in groups you can share ideas with some group members".*

*"OBE is a good method of teaching because it promote co-operation between learners and it allows learners to feel free when the teacher is teaching in terms of asking the questions, giving answers etc".*

*"I think OBE is better. When the educators are doing their 100% teaching students will progress".*

*“I think it is good sometimes because you understand a learner better than a teacher. Learners can help one another in case they don’t understand the teacher.*

Learners’ comments in favour of OBE revealed that OBE encourages group work and learners learn well from their peers. With OBE, educators are able to deal with big classes through group work.

According to Sieborger and Macintosh (2004:33), “outcomes-based education is an approach to teaching, training and learning which stresses the need to be clear about what learners are expected to achieve”. They further state that “outcomes-based education is a learner-centred, result-oriented approach based on the belief that all learners can learn and succeed” (Sieborger & Macintosh, 2004:33).

Spady (1994:8), who is seen as the father of OBE, highlights the viewpoint that what and whether learners learn effectively is more important than when and how they learn something. In OBE, “it is important to ensure that all learners will gain the necessary knowledge, skills and attitudes or to be successful lifelong learners, who will fulfill meaningful roles in real life, in and out of school” (Maree & Fraser, 2004:4). With regard to OBE, Spady (1994:9), formulated three assumptions:

- All learners can learn and succeed, but not on the same day in the same way.
- Successful learning promotes even more successful learning.
- Schools control the conditions that directly affect successful school learning.

The three assumptions serve as the rationale for the actual implementation of OBE, guided by its four principles (Spady, 1994:11-20; Spady & Marshall 1991:67). According to Spady, there is no one model for OBE, but OBE’s

purposes will be achieved if educators apply the following four principles consistently, systematically, creatively and simultaneously:

- Clarity of focus on culminating exit outcomes of significance.
- Expanded opportunity and support for learning success.
- High expectations for all to succeed.
- Design down from one's ultimate, culminating outcomes.

In the South African context, the designing-down process must start with the critical outcomes, which are broad, generic and cross-curricular, and refer to real-life roles. The next step will be to design down towards the key building blocks on which the critical outcomes depend, namely, the specific/learning outcomes and the lesson outcomes. The last step in the designing down process is to determine which developmental (discrete) outcomes will enhance and support the performance of the critical outcomes, and to include them in the development of the learning experiences and/or programmes (Maree & Fraser, 2004:6). According to Spady (1994:53):

Specific content and skills are important in OBE because the golden rules of design down require that educators build into their curricula both the knowledge and competence bases that are critical for learners to develop and ultimately apply (omit unimportant knowledge and skills).

- Implementation should allow for inputs from the wider community.

Learners' comments not in favour (negative comments) of OBE:

*"I think OBE is not good for us because if we sit in groups we always make noise and we do not do work for ourselves we always copy work from other members of the group. But it is also useful because we can help each other when we lack in our studies".*

*“OBE is not good because it is still using the old method of teaching which the one is that we using, so it can not work”.*

*“I think OBE must be in primary schools or else be used in high schools for those who need it”.*

The findings on learners’ view on OBE somehow agree with the findings by Coetzee (2008) which revealed that some students also commented in favour of OBE and some did not favour OBE at all. The students’ diverse ideas about OBE were expressed as follows according to Coetzee’s findings:

“I think it’s good, because learners work in groups in a classroom, as a result they are able to exchange ideas”.

“Lazy students don’t participate.”

“Comple waste of time”

“Was a good initiative that encouraged group work and peer-to-peer evaluation”.

“It was a great way for us to pass, but made a person lazy to work.”

“I don’t think it did any good for me, because I struggled when I got to Grade 10.”

“It’s boring and it limits us from thinking”.

Generally, from these findings, learners in favour of OBE looked at OBE as an approach that encourages group work. Learners not in favour see OBE as a waste of time and as an approach that promote laziness. However, research shows that interactive engagement is effective in promoting promoting students conceptual understanding (Hake, 2002). OBE is has its own advantages and disadvantages like all other approaches, but it is good in promoting interactive engagement among learners.

#### 4.7.4 Conceptual Difficulties in Mechanics

Mechanics is an essential prerequisite for most of the rest of physics. Therefore, the learner's initial knowledge of mechanics is most critical to his or her subject (physics) performance, so this study was restricted to that domain of physics. Droogan and Houston (2011) state that "successful learning of mechanics depends on the three aspects which are,

- (a) being able to understand the principles involved,
- (b) being able to cope with the mathematics ,
- (c) being able to relate these two aspects to everyday life".

Conceptual difficulties are widespread in physics. Section B, Part I of the TBM centred mainly on problem solving, requiring conceptual understanding and the application of the physics principles, rules, laws and theorems. Some learners could not attempt questions under this section with the reason that they could not understand the concepts underlying formulas. Relying on formulas is an indication of little conceptual understanding. Clement (1987:1) posits that

While taking physics many students can be described as *formula centred* both in their knowledge of physics and in their approach to problem solving. They are able to solve some problems that require only plugging numbers into formulas and manipulating those formulas, but are still unable to solve some very basic qualitative problems. Certain patterns of common qualitative errors across students and problems indicate that many students possess a variety of common misconceptions which can produce repeated errors.

In this regard, Clement (1987) further states that subjects need to place increased emphasis on conceptual understanding at qualitative level. Redish, Saul and Steinberg (1997) maintain that "students...have considerable difficulties with the fundamental concepts of Newtonian mechanics." Learners experienced conceptual difficulties with regard to work, energy and resolving the components of the weight.

Furthermore, Giancoli (1991, 1998, & 2000) states that it is very important to know the definitions, terminologies, and the basic principles and laws that apply. The general approach to problem solving is of great help if followed correctly. However, problem solving cannot be overemphasised at the expense of concept understanding. Regarding conceptual understanding, Michael (1992) states that instruction designed to teach scientific concepts can be divided into activities consisting of three phases: (a) identification of a concept; (b) demonstration of the concept; and (c) application of the concept.

This study revealed the following conceptual difficulties with regard to mechanics, particularly dynamics:

- Work-energy theorem application;
- Principle of conservation of mechanical energy application;
- Kinetic energy concept;
- Finding the net force;
- Work done by the net force;
- Solving problems involving motion on the inclined surfaces;
- Identification of balanced forces and uniform motion;
- Resolving components of vectors, of the weight in particular;
- Calculating the work done by friction, gravity, normal force and applied force, for motion on the inclined surface; and
- Understanding the concepts underlying the formulas that are used in calculating work and energy.

Kim and Pak (2002) in their investigation of the relation between traditional physics textbook problem solving and conceptual understanding found that students did not have much difficulty in using physics formulas and mathematics. However, they also found that students still had many of well-known conceptual difficulties with basic mechanics. Furthermore, they also found that there was little correlation between the number of problems solved and conceptual

understanding. They finally concluded that “traditional problem solving has a limited effect on conceptual understanding” (Kim & Pak, 2002:2).

In the same vein, Redish, Saul and Steinberg (1997:1) Droogan and Houston also assert that “it has been demonstrated that students can cope very well with the mathematics involved but they are not able to relate their knowledge to everyday life”. They further aver that students have probably been successful by learning techniques which solve a problem, but they have not really understood the principles involved. In this regard, the NCS promotes teaching the content as well as context, that is, application of the content learnt in physics to real life situations. Furthermore, the NCS does not promote teaching learners formulas but it does promote teaching learners concepts underlying a particular formula for problem solving purposes. With regard to this study, learners had difficulties with the mechanics concepts that underlie formulas and hence they could not solve problems that involved such concepts.

With regard to problem solving Giancoli (1991, 1998 & 2000) provides a general approach that is of some help in problem solving. The general approach is outlined as follows:

- Read written problem carefully. A common error is to leave out a word or two when reading, which can completely change the sense of a problem.
- Draw an accurate picture or diagram of the situation. Use arrows to represent vectors such as velocity or force and label the vectors with appropriate symbols.
- Choose a convenient x-y coordinate system. Vectors can be resolved into components along these axes.



- Determine what the unknowns are – that is, what you are trying to determine.
- Decide what you need in order to find the unknowns. (a) It may be of help to see if there are one or more relationships (or equations) that relate the unknowns to the knowns. But be sure the relationship(s) is applicable in the given case. Beware of formulas that are not general but apply only in a specific case. (b) It is also helpful to determine what information is relevant, what is irrelevant, in a given situation or problem.
- Try to solve the problem roughly, to see if it is doable (to check if enough information is given) and reasonable. Use your intuition, and make rough calculations. A rough calculation, or a reasonable guess about what the range of final answer might be, is a very useful tool. And a rough calculation can be checked against the final answer to catch errors in calculations (such as in the power of 10).
- Solve the problem, which may include algebraic manipulation of equations and/or numerical calculations. Be sure to keep track of units, for they can serve as a check.
- Again consider if your answer is reasonable.

With regard to work-energy theorem, energy transformation and energy conservation, Arons (1999:2) states that “the work-energy theorem, derived from Newton’s Second Law, applies to the displacement of a particle.” Aron (1999:2) further maintains that “work-energy theorem is not a valid statement about energy transformations when work is done against frictional force or action on or by deformable bodies.” With regard to energy conservation, Arons (1999:2) posits that

to use work in conservation of energy calculations, work must be calculated as the sum of the products of the forces and their corresponding displacements at the locations where the forces are applied to the periphery of the system under consideration. Failure to make this conceptual distinction results in various errors and misleading statements widely prevalent in textbooks, thus reinforcing confusion about energy transformations associated with the action in everyday experience of zero-work forces such as those present in walking, running, or accelerating the car.

The principle of conservation of energy and the work-energy theorem are two different principles that are applied in different situations under dynamical conceptions. Goldring and Osborne (1994) in their study on students' difficulties with energy and related concepts, stated that a high percentage of students do not understand some of the key concepts of energy. In this regard, SpringerLink (2007) holds that "the growing awareness of serious difficulties in the learning of energy issues has produced a great deal of research, most of which is focused on specific conceptual aspects". The main concern here is the learners' conceptual understanding in mechanics.

Trumper and Gorsky (1996:2) in their study about force conceptions of Israeli Physics students, they analysed their findings by means of two-part written questionnaire. Their findings revealed that physics students:

- Have considerably less difficulties when dealing with force in static situations than in dynamic ones;
- Mostly failed to affirm that the forces on an object are balanced during uniform motion;
- Were not able to distinguish between uniform and changing motion;
- Most recognised weight as a force, but had difficulties in knowing its direction;
- Were inconsistent in identifying the concepts of gravity and weight; and

- Were mostly ambivalent about affirming that motion and force need not be in the same direction.

Regarding the findings by Trumper and Gorsky (1996), this study revealed that learners had alternative conceptions with regard to force in static situations. Similar to their findings, this study revealed that learners had conceptual difficulties with regard to dynamical concepts (force, work and energy). A number of learners were having difficulties in identifying balanced forces. With regard to the concepts of weight and gravity, learners could not resolve the components of the weight. Hence, they were having difficulties in finding the work done by gravity for motion on the inclined surfaces.

Research also show that students experience conceptual difficulties with regard to acceleration and tension (McDermott, Shaffer & Somers, 1992). In their study on research as a guide for teaching introductory physics, found that traditional instruction did not enhance student understanding of dynamics. They further stated that “some difficulties were so severe that meaningful learning could not occur” (McDermott, *et al*, 1992:54). Furthermore they posited that “a single encounter is almost never enough to effect a significant conceptual change. Practice in more than one context is necessary” (McDermott, *et al*, 1992:54). Finally, they concluded that “serious conceptual and reasoning difficulties cannot be overcome through teaching by telling. To develop a functional understanding, students must move from passive to active participation in the learning process” (McDermott, *et al*, 1992:54). Teaching by drilling also helps and it is never outdated. Learners need to be given multiple opportunities to apply the same concepts and reasoning in different context, to reflect on these experiences, and to generalise from them (McDermott, *et al*, 1992).

#### 4.7.5 Alternative Conceptions in Mechanics

Research shows that a majority of the students reveal a variety of alternative conceptions about motion, particularly the trajectories of the falling bodies (Camarazza, McCloskey & Green, 2002). The notion that students come to science classes with alternative conceptions has become quite widely accepted by those who follow or participate in education research (Hammer, 1996). By way of definition, alternative conceptions in science education are ideas differing from accepted scientific explanations (Bayraktar, 2008). Bayraktar (2008) further posits that research reveals that alternative conceptions mainly originate from persons' experiences with the real world that seem very logical to them. Similarly, Droogan and Houston (2011) also state that alternative conceptions are deduced from personal experience or even from what learners have read or seen on television.

Thus, being very resistant to change, alternative conceptions inhibit the learning of the scientifically correct ideas (Bayraktar, 2008). This study revealed that learners held alternative conceptions in mechanics, particularly the kinematical concepts (position, speed, velocity and acceleration) and dynamical concepts (force and Newtonian Laws). Hestenes and Wells (1992:3) posit that "kinematics is the most difficult topic in elementary mechanics". They further maintain that kinematics may be the most fundamental as well, "for, as Newton asserted in the preface to his *Principia*, it is from the motion that we discover the forces" (Hestenes & Well, 1992:3). Regarding the kinematical concepts, projectile motion was used to determine the alternative conceptions about position, speed and acceleration. The following most prevalent alternative conceptions accompanied by learner quotations as well as the conventional science, were identified:

- Both the acceleration and velocity increase when a projectile is projected vertically upwards.

*“I think acceleration increases as the stone goes up”.*

*“Increasing velocity results in an increase in acceleration for the upward motion”.*

*“While the stone is accelerating upwards, the velocity is increasing”.*

According to Giancoli (2000) projectiles in motion have zero velocity at their greatest height. Projectiles take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch. In many cases the effect of air resistance is ignored. Again, in many cases the process by which the object is thrown or projected is not the issue of concern. Only the motion of a projectile after it has been projected and moving freely through the air under the action of gravity alone is considered. Thus, the acceleration of the object is that gravity,  $g$ , which acts downward with magnitude  $g = 9.8 \text{ m.s}^{-2}$  (Giancoli, 2000). Gravitational acceleration is the constant acceleration that a free falling object experiences due to gravitational attraction of the earth in the absence of air resistance, whether the object is moving upwards or downwards

Regarding the kinematical concepts, velocity and acceleration, here learners lost sight of the vector nature of these concepts. Hestenes, Wells and Swackhamer (1992) in their research study also determined that students held alternative conceptions with regard to position, velocity and acceleration. In their report they mentioned the following alternative conceptions with regard to kinematical concepts, that is, position, velocity and acceleration:

- Position-velocity undiscriminated;
- Velocity-acceleration undiscriminated; and
- Nonvectorial velocity composition.

In same vein, Heiko and Marco (2000:1) posit that “throwing and catching balls or other objects is a generally highly practiced skill; however, conceptual as well as perceptual understanding of the mechanics that underlie this skill is surprisingly poor”. The results of this study concurred with the findings by Heiko and Marco

(2000) who stated that paper-and-pencil tests revealed that up to half all student mistakenly believed that a ball would continue to accelerate after it has left the thrower's hand. Learners stated that the acceleration increases as the stone goes up.

Research conducted by Berry and Graham (1990, 1991, 1992), Jagger (1988) and Trowbridge and McDermott (1980, 1981), revealed that there were alternative conceptions in the students' understanding of mechanical concepts, in particular, velocity, speed, acceleration and force. In their study, the following alternative conceptions were identified:

- Some students used a position criterion to determine speed;
- While others associated 'being ahead' with 'being faster'; or
- Believe that when one object catches up with another object and is alongside it they both have the same speed;
- Some students used a position criterion to determine acceleration;
- Other students either associated the direction of acceleration with the direction of motion; or
- Thought that increasing speed meant increasing acceleration.

With regard to falling bodies, learners also revealed another alternative conception when they stated that *"the stone that is dropped moves with a constant velocity"*. The empirical study agrees that such an alternative conception once existed. Tillery, Enger and Ross (2007:29) and Tillery (2009:32) stated that the Greek philosopher Aristotle "had it all wrong when he reportedly stated that a dropped object falls at a constant speed that is determined by its weight". Regarding these kinematical concepts, an explanation needs to be provided as to what happens exactly with regard to projectile motion, particularly position, speed, velocity and acceleration. The role played by friction (air resistance), when not ignored, is important as well as force of gravity.

With regard to acceleration and velocity, Giancoli (2000:34) further mentions two other common alternative conceptions that are related to projectile motion: (1) “that acceleration and velocity are always in the same direction and (2) that an object thrown upward has zero acceleration at the highest point”. The same alternative conception as (1) above came up as the learners were answering question 17 of the TBM (Appendix A). Learners stated that “*the direction of both velocity and acceleration is same as the stone moves upwards*”. However, this alternative conception was not the most prevalent alternative conception for this study. The qualitative analysis of this study further revealed that learners held the same alternative conception as in (2) above. In this study, this alternative conception is reflected as AC 7 in sub-section 4.3.2.7. this was one of the most prevalent alternative conceptions revealed in this study.

A projectile in the vertical motion “has an initial velocity but then reaches a maximum height, stops for an instant, then accelerates back towards earth” (Tillery, Enger and Ross 2007:29 and Tillery 2009:32). Taking a ball that is thrown vertically upwards and returning back as an example, they further posit that

gravity is acting on the ball throughout its climb, stop, and fall. As it is climbing, the force of gravity is continually reducing its velocity. The overall effect during the climb is deceleration, which continues to slow the ball until the instantaneous stop. The ball then accelerates back to the surface just like a ball that has been dropped (Tillery, Enger and Ross, 2007:34 and Tillery, 2009:38).

In the same vein, Ostdiek and Bord (2008:61) aver that

a net force that acts opposite to the direction of motion of an object will cause it to slow down. If the force continues to act, the object will come to a stop at an instant and then accelerate in the direction of the force, opposite its original direction.

This is what happens when a projectile is thrown vertically upwards.

Regarding the dynamical concepts, a number of alternative conceptions with regard to force were identified. The following alternative conceptions accompanied by learner quotations, were identified:

- Force is needed to keep an object moving at all times.

*“A force is always needed to keep an object moving”.*

*“An object can only move when there is a force applied”.*

This alternative conception existed long ago. Tillery, Enger and Ross (2007:29) and Tillery, (2009:32) states that “the Greek philosopher Aristotle incorrectly thought that an object moving across earth’s surface requires a continuously applied force to continue moving.” They further posit that “it took about two thousand years before people began to correctly understand motion” (Tillery, Enger and Ross (2007:29) and Tillery, (2009:32). Object moving with a constant velocity on a straight line have zero acceleration and hence zero net force according to Newton’s Second Law of motion. Therefore an object can be in motion without the net force being applied on it.

- Action-reaction force pairs act at different times.

*“Because Newton’s Third Law agrees that both forces are exerted in different times on different objects”.*

*“If object A exerts a force on object B, then they will both be exerted at different times”.*

The empirical study reflects that action-reaction pairs take place at the same time. Tillery, Enger and Ross (2007: 40) and Tillery (2009: 45) state that “a single force does exist by itself. There is always a matched and opposite force that occurs at the same time.” The empirical study also reflects that action-reaction pairs act on different objects. Tillery, Enger and Ross (2007: 41) and



Tillery (2009: 45) further state that “the third law states that forces always occur in matched pairs that act in opposite directions and on two different bodies.” To illustrate this law, Kirkparick and Francis (2010) use an example of a racket exerting a force on a ball. They state that

the ball is squashed by the force of the racket *on the ball*; at the same time, the racket strings are stretched by the force of the ball *on the racket*. At the same time the racket is exerting a force on the ball, the ball is exerting an opposite force on the racket (Kirkpatrick & Francis, 2010:49).

Newton referred to these forces as action and reaction, and they are often known as action-reaction pair. In this regard, Kirkpatrick and Francis (2010:50) opine that “because the two forces are equivalent, it doesn’t matter which one is called the action and which the reaction.”

- No motion implies no force (static objects).

The following learner quotations were based on question 23, about a book at rest on the table.

*“The book on the table exerts no force on the table since it is not moving”.*

*“Because both of them are not moving, they both have no weight so they are not exerting any force”.*

*“Neither the table nor the book exert a force since they are both at rest”.*

*“They are both at rest and only potential energy is what they have”.*

With regard to static objects, Brown (1994) in his study about facilitating conceptual change using analogies and explanatory models found that high school students also believed that the table would not exert an upward force on a book resting on it. One of the effects of force is that it can cause no noticeable effect when applied on an object.

- Greater mass implies greater force as related to Newton's Third Law of Motion.

The following learner quotations were based on question 25, about a mosquito landing on top of the monument.

*"I think it is because the mosquito has a smaller weight than the monument".*

*"I am fairly confident because the monument has got a bigger mass as compared to the mosquito and hence the monument exerts a larger force to the mosquito although they both apply a force on each other".*

*"Because the monument is bigger than the mosquito".*

*"Because the mosquito has zero mass compared to the monument, so only the monument exerts the force".*

*"Because the monument is bigger than the mosquito".*

With regard to this alternative conception and learners' statements, Kirkpatrick and Francis (2010) make an illustration of a ball with a weight of 10 newtons falling freely towards the earth's surface when air resistance is ignored. Earth's gravity pulls the ball downward with a force of 10 newtons and the ball exerts an upward force on the earth of 10 newtons. Kirkpatrick and Francis (2010:50) posit that "common sense may tell you that earth must exert a larger force because it is larger, this is not true. No matter what the origin of the forces...the forces must be equal in size and opposite in direction". Griffith (2007) uses an example of a book resting on the table. He states that "the earth pulls down on the book with the force  $W$ , and the book pulls upward on the earth with the force  $-W$ " (Griffith, 2007:68). The minus sign indicates that upward pull on the earth is in the opposite direction. The two forces are equal in magnitude and opposite in directions. Therefore, according to Newton's Third Law of motion, greater mass or greater weight does not imply greater force.

- Only active agents exert forces and similarly, the most active agents exert greatest forces.

The following learner quotations are based on question 24, about a stubborn goat pushing against the wall

*“A goat has a larger force than the wall”.*

*“The wall is not moving”.*

Questions 23, 24 and 25, the target concept involved the common alternative conception that static objects are unable to exert forces. Learners maintained that *“a table does not exert a force upward on a book resting on it”*. The reason given by the learners was that both the table and the book were not moving.

Furthermore, Hestenes, Wells and Swackhamer (1992) in their research results obtained by the use of the FCI, reported the following findings (taxonomy of alternative conceptions probed by the inventory) which agree with the findings of this study with regard to static objects, force, Newton’s Third Law of motion and active agents:

- Only active agents exert forces;
- Motion implies active force;
- No motion implies no force;
- Greater mass implies greater force; and
- Most active agent produces greatest force.

Regarding Newton’s Third Law of motion (action/reaction pairs), Hestenes, *et al* (1992:5) further posit that “students often interpret the term ‘interaction’ by a conflict metaphor’. They see an interaction as a ‘struggle between opposing forces.’ It follows from the metaphor that ‘victory belongs to the stronger’”. Students also confused the balance of forces on a single object with the equal and opposite forces on different objects in an interacting pair (Hestenes, *et al*, 1992).

Giancoli (2000:83) argues that “we tend to associate forces with active bodies such as humans, animals, engines, or a moving object like a hammer”. Giancoli (1991) further posits that “it is often difficult to see how an inanimate object at rest, such as a wall or a desk, can exert a force”. Learners could also not see how a table could exert an upward force on the book resting on it. Giancoli (2000:83) gives the following explanation: “every material, no matter how hard, is elastic, at least to some degree...And just as a stretched rubber band exerts a force, so does a stretched (or compressed) wall or desk”. Therefore, a static object does exert a force.

To overcome the alternative conceptions, Bayraktar (2008) opines that “it is very important for science educators to diagnose alternative conceptions of students about a particular topic before introducing the concepts related to it. In same vein, Droogan and Houston state that “teachers should try to ensure that alternative conceptions are challenged and discussed immediately, otherwise students will find it very difficult to understand completely the processes and modelling in the physical world” ([www.infj.ulst.ac.uk/hypotenuse/droogan.html](http://www.infj.ulst.ac.uk/hypotenuse/droogan.html), cited on the 26<sup>th</sup> of May 2011). Hestenes, Wells and Swackhamer (1992) state that alternative conceptions can be successfully overcome only when something better (namely, Newtonian concepts) is available to replace them. Hestenes, Wells and Swackhamer (1992) further state that one great strength of Newtonian mechanics is that it is a coherent conceptual system, and can have much impact on student learning as it did on the scientists adopting the system in the first place.

#### **4.7.6 The Effectiveness of the Interventions**

Jimoyiannis and Komis (2001:1) state that “a major research domain in physics education is focused on the effects of various types of teaching interventions aimed to help students’ alternative conceptions transformation.” Of the three interventions (traditional, OBE and blended), the blended approach came out as

the most effective teaching and learning strategy. The blended approach, a mixing of different teaching and learning environments, was mainly manifested in combining face-to-face instruction with computer-mediated instruction (Graham, 2006; Imenda, 2010) as well as interactive engagement modalities. Bonk and Graham (2006:221) avers that “the future requires blended learning since with the infusion of various technologies and communication mode into our lives; we are surrounded by a blending world which will be more blended in the future.” This type of the approach tended to be more effective mainly because it catered for different learner characteristics, as Imenda (2010:3) avers, “different learners learn best through different approaches.” As stated above, this study included computer-mediated teaching and learning. Jimiyiannis and Komis (2001) state that “computer simulations are applications of special interest in physics teaching because they can support powerful modelling environments involving physics concepts and processes.” In their study, two groups (control and experimental) of 15 – 16 years old students were studied to determine the role of computer simulations in the development of functional understanding of the concepts of velocity and acceleration in projectile motion. Both groups received traditional classroom instruction on these topics; the experimental group used computer simulations also (Jimiyiannis and Komis, 2001).

Their groups were about of the same age as the four groups studied in this research study. The assumption therefore is that their group were doing the same grade as the groups group studied in this research. The difference is that they compared two modes of teaching whereas this study compared three mode of teaching. Their findings revealed that “students working with simulations exhibited significantly higher scores in the research tasks” (Jimoyiannis and Komis, 2001:2). They further concluded that “computer simulations may be used as an alternative instructional tool, in order to help students confront their cognitive constraints and develop functional understanding of physics.” Hence, it was the same case with blended approach used in this study. Computer-

mediated instruction was part of this approach. This approach is therefore somehow receiving confirmation from the previous researchers.

Regarding traditional approach, researchers state that this approach to teaching and learning induces only a small change in learners' initial qualitative, common-sense beliefs about motion (Hestenes & Halloun, 1985; Hake, 1997). The findings of this study revealed that the traditional approach intervention group exhibited significantly lowest scores in the TBM as compared with the OBE and the blended groups. Pride, Vokos and McDermott (1998:150) posit that "teaching by telling is an ineffective mode of instruction for most students." In the same vein, McDermott, Shaffer and Somers (1993) in their study also concluded that traditional instruction did not enhance students' understanding of dynamics. With regard to the implementation of the traditional approach and learners achievement using this approach, this study concurs with the findings by other researchers mentioned in this section and in the literature review.

It has been said that the average normalised gain ( $g$ ) is a much better indicator of the effectiveness of the treatment (Hake, 1997). In this regard, the traditional intervention had low average normalised gain [ $g = 0,20$ ]; OBE treatment had medium gain [ $g = 0,30$ ]; and the blended intervention had medium gain [ $g = 0,60$ ] which was closed to the high gain [ $g = 0,70$ ]. With regard to the three interventions, the blended approach to teaching and learning was the most effective treatment to help alleviate conceptual difficulties and alternative conceptions of students in mechanics. A low score on the BMT indicated a lack of understanding of the basic concepts of mechanics as it happened with the traditional approach (Hake, 1997).

According to Hake (2002) and Hunt (2002) the standardised physics assessment instruments and old 'normalised gain'  $g$  has shown that (1) the traditional mode of introductory physics instruction (passive student lectures, recipe labs, and algorithmic problem examination) is relatively ineffective in promoting students

conceptual understanding, even when employed by teachers who receive high student evaluation; and (2) 'interactive engagement (IE) methods' can be much more effective than 'traditional' (T) methods in promoting conceptual understanding of mechanics. With regard to the blended approach, there was a lot of learner-learner interaction through group discussions and also a lot of learner-teacher interaction through question and answer, discussions and during the giving of the feedback to learners. It is evident from the 'normalised gain'  $g$  that there were not much interactive engagement methods employed in the OBE intervention. However, the class average normalised gain ( $g$ ) for BMT does not provide a definitive assessment of the overall effectiveness of an introductory physics class (Hake, 1998). Hake (1997) avers that the class average normalise gain assesses only the attainment of a minimal conceptual understanding of mechanics. In this regard, interactive engagement methods appear, on average, to be much more effective than traditional methods.

For improvement in learner performance, Hake (1998) makes suggestions that improvement may occur through:

- Use of interactive engagement methods in all components of the subject (Physical Science) and tight integration of these components;
- Administration of examinations in which in which a substantial number of the questions provoke the degree of conceptual understanding induced by IE methods;
- Physics educators who wish to improve the performance of physical science pass rate to seriously consider the IE strategies in their teaching and learning;
- Early recognition and positive intervention for potential low gain students/learners;

- Explicit focus on the goals of science and methods of science, that is, (LOs and ASs) (including operational definitions);
- More personal attention to students by means of human-mediated computer instructions in some areas; and
- More widespread use of standardised tests by individual instructors so as to monitor the learning of their learners.

## 4.8 CONCLUSION

In this chapter, results were presented and discussed. The main aim or object of this chapter was to answer the three research questions and also to test the hypotheses. The first two research questions were answered through content analysis whereas the third research question was answered through statistical hypothesis-testing. The most prevalent conceptual difficulties and alternative conceptions in mechanics were identified and categorised. The results of this study show that learners have conceptual difficulties in mechanics particularly with regard to dynamical concepts, that is, force, work and energy. The most prevalent conceptual difficulties are related to the application of the principle of conservation of mechanical energy, work-energy theorem for motion on the inclined surfaces as well as finding work done by friction, applied force and gravity.

The results of the study also show that learners hold alternative conceptions with about mechanics, particularly concerning kinematical concepts such as, position, velocity, speed and acceleration. The study also revealed that learners hold alternative conceptions with regard to the dynamical concept of force and Newton's third law of motion. This study identified the following alternative conceptions: (a) the velocity and acceleration of a projectile increase as it goes



up; (b) the weight, or mass, of an object has an effect on the magnitude of the force it exerts; (c) force is needed to keep an object moving at all times; (d) only active agents exert force; (e) objects that are not moving do not exert force; (f) action-reaction forces occur at different times; (g) at the highest point, the acceleration of a projectile is zero; and (h) motion implies active force.

The empirical study indicates that conceptual and reasoning difficulties cannot be overcome through teaching by telling (lecture method) but by active participation of learners in the learning process (McDermott, et al, 1993). (McDermott, et al, 1993) further maintains that traditional instruction does not enhance learner understanding of dynamics. The empirical study also indicates that alternative conceptions can be overcome if educators challenge and discuss them immediately. They will also be overcome if educators diagnose alternative conceptions about a particular topic before introducing the concept related to it (Bayraktar, 2008).

The results showed that all the three interventions significantly alleviated conceptual difficulties and alternative conceptions of the learners in mechanics. It may then be said that all methods of teaching and learning should be used to accommodate different learner characteristics since learners learn in different ways.

With regard to the most effective teaching strategy, the blended approach came out as the most effective strategy for alleviating both conceptual difficulties and alternative conceptions. The most effective approach was determined through the use of the “average normalised gain” concept complemented by ANOVA. After the interventions the three groups performed significantly better in varying degrees. From the hypotheses tested, this study concludes that the blended approach is the most effective approach in alleviating the conceptual difficulties and alternative conceptions in mechanics. The next chapter gives the summary, conclusion and recommendations for future study.

## **CHAPTER FIVE**

### **SUMMARY, CONCLUSION AND RECOMMENDATIONS**

#### **5.1 SUMMARY**

This chapter recapitulates the aim, the conceptual framework, the methodology followed and major findings of the study. The study also had four hypotheses that were tested and which were meant to answer the third research question.

##### **5.1.1 Aim**

The study sought to find ways to alleviate conceptual difficulties and alternative conceptions in mechanics for Grade 12 physical science NCS curriculum. In this regard, this study focused on conceptual physics. By way of description, “conceptual physics focuses on comprehension and understanding of physics concepts, without the mathematical emphasis that characterises the traditional physics approach” (Hassard & Dias, 2009:201). From the researcher’s experience, there were problem-solving exercises and activities that challenged learners. Grade 12 physical science NCS curriculum has six (6) knowledge areas. The researcher chose mechanics as the most challenging knowledge area to learners. This knowledge area contributes about 33% of paper one in the final National Senior Certificate (NSC) examination, which translates to 50 marks out of a total of 150 marks. Thus, in sequential order, this study first sought to determine the most prevalent conceptual difficulties experienced by learners with regard to mechanics, as well as identify the most prevalent alternative conceptions relating to mechanics. Subsequently, curriculum interventions based on the traditional, OBE and blended instructional approaches were developed and implemented with the aim of finding ways of alleviating the identified conceptual difficulties and alternative conceptions in mechanics.

When analysing and commenting on the performance of Grade 12 physical science learners in 2010, the Department of Education Physical Science Analyst stated that the basics of mechanics “were not attended to during the teaching and learning” (Department of Education, 2010:1). This suggested that the way teaching and learning took place in classes contribute to the increase of the conceptual difficulties in the learners’ mind and hence less alleviation of the alternative conceptions. The analyst further recommended that more educator workshops should be organised on topics like *work, energy and projectile motion*. This also suggested that more workshops were needed for physical science educators in content knowledge as well as in pedagogical knowledge. In dealing with the alternative conceptions, Brown and Clement (1987) maintain that alternative conceptions are widespread and resistant to change – and that learners come to the science classroom with a number of alternative conceptual frameworks which inhibit the learning and understanding of certain concepts. In particular, the aim of this study was basically fourfold:

- To determine the conceptual difficulties experienced by Grade 12 physical science learners with regard to mechanics.
- To identify most prevalent alternative conceptions relating to mechanics amongst grade 12 physical science learners.
- To develop and implement curricular interventions, based on the traditional, OBE and Blended approaches, to alleviate the identified conceptual difficulties and alternative conceptions.
- To ascertain the effectiveness of the traditional, OBE and blended interventions in ameliorating learners’ conceptual difficulties and alternative conceptions.

Thus, this study sought to find answers to the following critical research questions:

- What are the conceptual difficulties experienced by Grade 12 physical science learners in mechanics?
- What are the most prevalent alternative conceptions relating to mechanics among grade 12 physical science learners?
- Which intervention(s) among the traditional, OBE-based and the Blended approaches can best alleviate the conceptual difficulties and alternative conceptions relating to mechanics for grade 12 physical science learners?

The first and second research questions were addressed through content analysis. However, in order to address the third research question, a number of statistical hypotheses needed to be tested:

- An intervention based on a traditional instructional approach has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.
- An OBE instructional intervention has no significant effect in alleviating the conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.
- A Blended instructional intervention has a significant effect in alleviating the conceptual difficulties and alternative conceptions in mechanics.
- There is no statistically significant difference amongst OBE-based, traditional and blended instructional interventions in alleviating the

conceptual difficulties and alternative conceptions held by grade 12 learners in mechanics.

### **5.1.2 The Conceptual Framework**

Conceptually, this was a science education study which meant to look at the conceptual difficulties and alternative conceptions in mechanics. Regarding science teaching and learning, this study was based on the notions by Gagne`, Bruner, Jewey, Piaget, and other learning theorists. This includes constructivists and behaviourists learning theories. The activity theory formed part of this study since this was a science education study. It also looked at the most effective teaching and learning approaches that could help in the alleviation of conceptual difficulties and alternative conceptions in mechanics. The study combined both the natural sciences and the behavioural sciences in that physical science, specifically mechanics and teacher-learner/learner-learner interactions were points of focus. Poor performance by grade 12 physical science learners was the main reason that led the researcher to undertake this study.

### **5.1.3 Interventions**

There are certain learning outcomes and assessment standards expected to be achieved by physical science learners. Accordingly, curriculum interventions were developed and implemented. Accordingly, three curriculum interventions (traditional, OBE and blended) were developed and implemented. Regarding traditional intervention, lecturing or telling method and the use of only the prescribed textbooks as references were the dominant instructional approaches. The traditional intervention was almost teacher-centred and the students were passive recipient of information. There was little or no interaction among students and the teacher remained in complete control of the class proceedings.

With regard to OBE intervention, instruction involved an open interaction between the educator and the learners, as well as among the learners. The

researcher used intervention strategies which adhered to the notion of constructivism in the OBE intervention. A variety of instructional methods were used. This intervention involved interactive learner-centred instructional methods. Learners were encouraged to use other sources of information in addition to the prescribed textbook. Learners participated fully in the programme.

Regarding blended intervention, mechanics concepts and principles were treated according to the blended approach to teaching and learning. Blended approach mixes various event-based activities. This approach also used a variety of teaching and learning strategies. This intervention involved face-to-face classroom, open interaction between the teacher and the learners, interaction among the learners themselves, computer-mediated teaching and learning and co-operative learning. A continuum of teaching strategies was used in the clarification of mechanics concepts and principles.

Briefly, the traditional intervention was dominated by lecture or telling instructional methods and memorisation by the learners. The teacher was a disseminator of information. The OBE intervention was dominated by group discussions and an educator was regarded as a facilitator of learning. With regard to blended approach, all teaching strategies were vitally important since in a class of learners there are different learners' characteristics. The teacher was regarded as a facilitator of learning, researcher (Web-based learning) and a learner as well.

A number of conceptual difficulties and alternative conceptions were addressed through these three interventions. The blended approach was the most effective approach in alleviating the identified conceptual difficulties and alternative conceptions in mechanics.

The behaviourist and constructivist learning theories formed the basis for this study. The researcher believed that no single teaching or learning approach

could give success in alleviating the conceptual difficulties and alternative conceptions when used alone, but a continuum of teaching method could do. The thesis of the study was that the pass rate or performance in physical science would improve with quality result provided: (a) the most prevalent conceptual difficulties and alternative conceptions are alleviated by the use of the most effective strategies of teaching and learning; (b) educators attend to the basics during teaching and learning; and (c) are regularly professionally developed in pedagogical and content knowledge (PCK).

#### **5.1.4 The Methodology**

A quasi-experimental non-equivalent comparison-group research design was followed to investigate the extent to which the traditional, OBE and the blended approaches could help alleviate the conceptual difficulties and alternative conceptions held by high school learners in mechanics (Imenda & Muyangwa, 2006). The researcher sought to compare the effectiveness of different treatment modalities, that is, traditional, OBE and blended approaches. The study involved four (4) high schools drawn from Empangeni Education District. Learners from the four high schools formed four groups respectively. One of the four groups was used as a comparison group.

All the four groups were pre- and post-tested on the dependent variables, that is, conceptual difficulties and alternative conceptions. Thus, the teaching and learning approaches (traditional, OBE and blended) served as independent variables. The intervention for the comparison group was normal instruction that was prepared by the teacher at the school concerned. The treatments or interventions prepared by the researcher were administered to the remaining three groups. The differences in the post-test scores among the four groups were meant to indicate the effectiveness of the respective interventions.

Empangeni Education District grade 12 physical science learners constituted the target population of this study. The research sample consisted of 140 grade 12 physical science learners. Purposive sampling was used to select participating schools. Firstly, before the main study was carried out, a pilot study was carried out to see if the proposed direction of the study was viable. The basic purpose of the pilot study was to determine how the design of the main study could be improved and to identify the flaws in the measuring instrument (Kidder & Judd, 1986). The Test in Basic Mechanics (TBM) was used to collect information required to answer the three research questions and was used as both pre- and post-test. The questions were based on the targeted conceptual difficulties and alternative conceptions identified in the literature review and in the pilot study. The TBM was examined by two physical science specialists, two physical science subject advisors and the promoter, Professor S.N. Imenda for validity. The researcher personally visited schools to do interventions. The data was therefore collected through pre- and post-tests as well as through learners' comments during intervention. Ethical issues were considered during the whole process of the study.

The data collected was then qualitatively analysed. Quantitatively, it was statistically analysed using One Way Analysis of Variance (ANOVA). The concept of "normlised gain scores" was also used to determine the effectiveness of the interventions.

#### **5.1.5 Major Findings**

The major findings of this study mainly concern the conceptual difficulties, alternative conceptions as well as the effectiveness of the interventions.

#### **Conceptual Difficulties in Mechanics**

Regarding the main results of the study, qualitative analysis revealed the following five most prevalent conceptual difficulties in mechanics, particularly



relating to work and energy theory and principles for grade 12 physical science learners:

- Motion on Incline Planes/Surfaces and Components of Vectors

Learners encounter a challenge in solving problems that involve resolving *'the components of force or weight'*. This is more evident when solving problems that involve motion on incline planes/surfaces.

- Work Concept

To learners, *'work'* is simply the product of force and displacement, that is,  $W = F \cdot \Delta x$ . The issue of *'the component of the force'* is disregarded by learners. Thus, they cannot distinguish between *positive work* and *negative work* as well as *no work done*.

- Work-Energy Theorem (Application)

Learners reasonably understood work-energy theorem. This was evident when they were required to apply the theorem.

- Kinetic Energy

In the kinetic energy formula,  $K = \frac{1}{2} mv^2$ , learners are unable to recognize the relationship between mass and kinetic energy, and between velocity and kinetic energy.

- Principle of Conservation of Mechanical Energy

Learners fairly understand the Principle of Conservation of Mechanical Energy. This is evident when they apply the principle. Learners do not clearly understand the following concepts that relate to the principle: *'system'*, *'isolated or closed system'*, *'conservation'*, *internal forces*, *external forces* and *so on*.

These conceptual difficulties experienced by learners were identified during intervention as well as from the BMT responses.

### **Alternative Conceptions in mechanics**

In the same way, regarding the main results of the study, qualitative analysis also revealed the following eight most prevalent alternative conceptions in mechanics,

particularly relating to the kinematical concepts in projectile motion and dynamical concepts, that is, force; Newton's third law of motion:

#### Projectile motion

- The *velocity* and *acceleration* of the projectile motion *increase* as the projectile goes *up*;
- The *acceleration* of the projectile is *zero* at the highest point;

#### Force, Weight and Mass Concepts

- The weight, or mass, of an object has an effect on the magnitude of the force it exerts (Newton's Third Law of motion);
- Force is needed to keep an object moving at all times;
- Objects that are not moving do not exert forces;
- Only active agents exert forces;
- Action-reaction forces occur at different times; and
- Motion implies active force.

These five most prevalent alternative conceptions emanated from the learners TBM responses.

#### **The Effectiveness of the Interventions**

To determine the effectiveness of the three interventions, the average normalised gain concept was used. The purpose of using this concept was to determine which approach was the most effective among the three, that is, the traditional, OBE and the blended approach. The average normalised gains ( $g$ ) for the respective interventions were 0,2; 0,3 and 0,6. According to Hake (1997) ( $g$ ) is a much better indicator of the extent to which a treatment is effective. If the treatment yields  $(g) > 0,3$ , then the treatment could be considered as in the "interactive-engagement zone" (Hake, 1998; Meltzer, 2002). More specifically, "high gain" is defined as the one with  $(g) \geq 0,7$ ; "medium gain" with  $0,7 > (g) \geq 0,3$ ; and "low gain" with  $(g) < 0,3$  (Hake, 1998). The results indicated that the traditional intervention was not in the 'interactive-engagement zone' since its normalised gain was 0,2. This means the interactive-engagement methods were

poorly or not used at all. The results also showed the OBE intervention to fall in the 'interactive-engagement zone' as the average normalised gain was 0,3. This means the interactive-engagement methods (for example, group discussions) were used. The blended intervention was also in the medium gain range  $[(g) = 0,6]$  which was the highest gain among the three interventions. In this way, the results indicated that the blended approach was the most interactive – and, indeed, the most effective approach among the three interventions used in this study.

## **5.2 CONCLUSION**

The research focused on the conceptual difficulties and alternative conceptions in mechanics, as well as a determination of the effective approach (es) to alleviate conceptual difficulties and alternative conceptions. The study involved 140 grade 12 physical science learners from the participating schools. These were divided into four groups of thirty five (35) learners in each group. The conceptual difficulties and alternative conceptions were identified through the Basic Mechanics Test (BMT) (pre-test). The conceptual difficulties were around the following mechanics topics or themes: “work energy theory and principles and application”, “motion on inclined surfaces/planes” and “components of vectors including weight”. In the same way, the alternative conceptions were around the following topics or themes: “projectile motion”, “force concept” and Newton’s Third Law of motion”.

An attempt was made to overcome or alleviate these conceptual difficulties and alternative conceptions. This was done through curriculum interventions, that is, traditional, OBE and blended approaches. Many alternative conceptions were resistant to change through the use of the traditional approach and relatively fewer through the use of OBE. With regard to the use of the blended approach, very few conceptual difficulties and alternative conceptions still remained after the intervention.

In conclusion, therefore, this study established that there were five conceptual difficulties experienced by Grade 12 physical science learners with regard to mechanics. These were: (a) motion on inclined planes and components of vectors; (b) work concept; (c) work-energy theorem (application); (d) kinetic energy; and (e) Principle of Conservation of mechanical energy. These conceptual difficulties served as an answer to the first research objective which sought “to determine the conceptual difficulties experienced by Grade 12 physical science learners with regard to mechanics.”

In the same way, this study identified eight most prevalent alternative conceptions relating to mechanics for grade 12 physical science. These were: (a) the velocity and acceleration of a projectile increase as it goes up; (b) the weight, or mass, of an object has an effect on the magnitude of the force it exerts; (c) force is needed to keep an object moving at all times; (d) only active agents exert force; (e) objects that are not moving do not exert force; (f) action-reaction forces occur at different times; (g) at the highest point, the acceleration of a projectile is zero; and (h) motion implies active force. These alternative conceptions served as an answer to the second research question which sought “to identify most prevalent alternative conceptions relating to mechanics among grade 12 physical science learners.”

A number of statistical hypotheses were tested to address the third research question. The statistical hypotheses related to the three interventions (traditional, OBE and blended approaches) developed. The results of this study showed that among these three approaches, the blended approach to teaching and learning is the most effective approach in alleviating conceptual difficulties and alternative conceptions in mechanics. Finally, it may be argued that the effectiveness of the blended approach lay in its capacity to accommodate the diversity of learning styles and needs of the learners.

### **5.3 RECOMMENDATIONS**

The main findings of this study have been presented and discussed. The recommendations that follow draw from the engagement with the research findings of this study.

5.3.1 Presently, physical science at the FET Band has four (4) periods per week. The number of periods per week should be increased to five (5) periods since educators need more time with their learners. Teacher-learner, learner-teacher and learner-learner interactions should be increased. The research findings revealed that Interactive Engagement methods of teaching and learning are more effective for conceptual understanding in physical science.

5.3.2 Educators should do a baseline assessment (pre-test) when introducing a new topic or knowledge area in order to accord themselves an opportunity to identify conceptual difficulties and alternative conceptions requiring attention. This can either be written assessment or verbal assessment.

5.3.3 Research shows that many alternative conceptions are preconceptions and hence are not alternative comprehensions (miscomprehensions) of presented material (Clement, 1987). Educators should not confuse alternative conceptions and preconceptions held by learners with low intelligence or poorly developed reasoning skills. Educators should be sensitive to such distinctions since this may have an impact on the way teachers view learners and on the way learners view themselves.

5.3.4 Some alternative conceptions were resistant to change in the face of the traditional lecture based teaching. This meant that a more powerful

teaching technique had to be devised. Thus, physical science educators should be encouraged to use the blended approach to teaching and learning in order to accommodate all learners in a class. Blended teaching and learning is mixing of different teaching and learning environments – mainly manifested in combining face-to-face instruction with the computer mediated-instruction. In one class of learners there are different learner characteristics. Learners learn in different ways like learning through lecture (telling), discussion, problem solving, practical work, discovering, experimenting, using pictures and diagrams, videos and demonstrations. According to Ausubel's two-dimensional learning continuum of rote learning versus meaningful learning (Novak, 1998), all instructional methods can lead to meaningful or rote learning. In teaching and learning, the emphasis should be on meaningful learning for improved performance.

5.3.5 Physical science educators should be encouraged to use preconceptions as well as alternative conceptions to advantage in the classroom. The existing knowledge structures need to be engaged with through presentation of a large number of examples. By so doing, learners can play an active role in questioning and modifying alternative conceptions. Clement (1987) further opines that in this manner, the natural conflict between “correct” and “incorrect” conceptions can be used to create controversy and cognitive dissonance that promotes active learning.

5.3.6 Physical science has laws, principles, rules and theorems which in turn have formulas and /or equations. Teaching should emphasise the understanding of concepts rather than recall of formulas and equations. In any case, some of the basic formulas and mechanics equations are normally provided during the time of tests and examinations.

- 5.3.7 It is difficult to cover some of the topics in the physical science curriculum without basic equipment at hand. The physical science analyst for final examination results alluded to the fact that the majority of the schools have nothing to use to assist educators to teach topics like force, linear momentum and projectile motion (Department of Education, 2010). The Department of Education should supply schools with basic equipment to effectively teach physical science.
- 5.3.8 Some the physical science educators have a challenge in preparing balanced and standardised question papers covering all the Learning Outcomes (LOs) and Assessment Standards (ASs). The analyst also stated that the majority of educators depend on questions set by the examiners in the previous question papers and common tests. In this way, learners are not exposed to all level of questioning, that is, lower and higher order questioning. The only time learners see the Synthesis questions is during the examinations. In this regard, there should be workshops for physical science educators based on preparing balanced and standardised question papers.
- 5.3.9 With regard to conceptual difficulties, there should be workshops based on pedagogy and content knowledge or else physical science educators should register with institutions of higher learning for such knowledge gain. More workshops should be organised to attend to topics like Work Energy Theory and Projectile Motion.

## **5.4 THE IMPORTANCE OF THIS STUDY**

In conclusion, therefore, it can be said that this study was important in the sense that the conceptual difficulties and alternative conceptions in mechanics were identified. The effective approach to overcoming these conceptual difficulties and alternative conceptions was also determined. The study explained how best

educators can use teaching and learning strategies, including technological resources, that are available and cheap to achieve optimum learner performance in physical science.

Blended teaching sometimes includes computer-mediated learning, that is, e-learning. Desk-top and laptop computers are sometimes expensive but cheaper devices called cellphones can also sometimes be used for the same purpose. In most cases, learners use cellphones for entertainment activities that do not add any value to their academic development. This is wrong use (misuse) of cellphones. All methods of teaching should be used to accommodate different learner characteristics since learners learn in different ways. The researcher learned that the following points are essential to overcome alternative conceptions and conceptual difficulties held by learners:

- The choice of the teaching and learning strategies;
- Basic equipment to teach concepts or to help learners understand mechanics concepts.
- Identification of the alternative conceptions and conceptual difficulties from any knowledge area of physical sciences since it is not only mechanics that has alternative conceptions.
- Alternative conceptions can be identified through the use of baseline assessment, that is, either a written pre-test or verbal questioning by the educator before beginning a new theme, topic or knowledge area.
- Interactive Engagement (IE) methods to be used more often by educator, that is, learner-learner; teacher-learner and learner-teacher interactions through discussion; question and answer; problem solving and other methods that falls under (IE). This has been proven through research including this study.
- At the end of learning session, there should be evaluation of some kind for example, post-testing, diagnostic or summative evaluation.



From the theoretical and conceptual framework, the researcher was able to develop the following model as the best way to teach physical science effectively and successfully. Table 5.1 shows the blended teaching and learning model to help educators improve learner achievement in physical science.

**Table 5.1** Blended Teaching and Learning Model

<b>WHO/WHAT</b>	<b>TEACHING STRATEGY</b>	<b>OBJECTIVE</b>
Educator	Baseline Assessment/verbal questioning/written work	To determine the alternative conceptions and conceptual difficulties
Educator	Leacture/telling method	To explain concepts/introduce topic,theme, knowledge area.
Learner-teacher/ teacher-learner	Discussion/question answer method	Explain concepts
Learner-learner	Discussion/ problem solving	Develop problem-solving skills
Educator	Demonstration	To further clarify cocncepts and to improve learner observation and recording skills.
CD-ROM/USB	Animation	Learners to observe behaviour of objects/particles subjected to different conditions
Desk-top/Laptop/Cellphone/Internet	e-learning	For further understanding/ assignments/homework.

Learners	Problem solving	For individual learner exercise.
Learners	Diagnostic/post-test	To check effectiveness.

Table 5.1 indicates different strategies that can be used to improve learner performance in physical science. The teaching strategies in Table 5.1 are not in the order of priority to avoid prescribing for educators. This model can be used even if there are no laboratories in schools.

Therefore, to achieve quality results in South Africa, the focus should be directed at improving and strengthening the culture of learning and teaching, effective resources provisioning, infrastructure and equipment for learning, furthering of teacher qualifications and continuous teacher development and support.

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## APPENDIX A

### TEST in BASIC MECHANICS (TBM) DURATION: 2hours

The aim of this test is to obtain respondents' biographical information and their preferences regarding instructional and assessment methods of learners, as well as to determine learners' familiarity with and understanding of selected concepts in mechanics. It will be helpful and appreciated if you complete this test as honestly and to the best of your ability as possible. The test consists of Sections A and B. Section B consists of Parts I and II. Please attempt all questions.

#### SECTION A

##### INSTRUCTIONS:

Please check with (X) in the appropriate box.

In case of open-ended questions, write in the space provided.

Do not write your name. All details are confidential.

##### 1. GENDER

Male	
Female	

##### 2. AGE

Under 15 Years	
15 Years	
16 Years	
Older than 16 Years	

##### 3. What is your home language (H.L.)?

Afrikaans	
English	
Isizulu	
Sepedi	
Sesotho	
Setswana	
Tshivenda	
Xitsonga	
Isixhosa	
Siswati	
Isindebele	
Other (Specify)	

##### 4. What is your first additional language (F.A.L.)?

Afrikaans	
English	
Isizulu	
Sepedi	
Sesotho	
Setswana	

Tshivenda	
Xitsonga	
Isixhosa	
Siswati	
Isindebele	
Other (Specify)	

5. Which instructional strategy (method of teaching) do you wish teachers to use when teaching?

Lecturing (Telling Method)	
Practical work	
Self-study	
Group work	
OBE	
Electronic learning (through the computer / internet)	
Other (Specify)	

6. What do you think of OBE?

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7. Which assessment method do you prefer when being assessed?

Continuous assessment (CA)	
Tests and examinations (T & E)	
Both CA and T & E	

8. Which of the following topics on mechanics sound familiar to you?

Speed	
Velocity	
Acceleration	
Weight	
Mass	
Momentum	
Projectile motion	
Work and energy	
Force	
Newton's laws of motion	
Free falling bodies	



## SECTION B

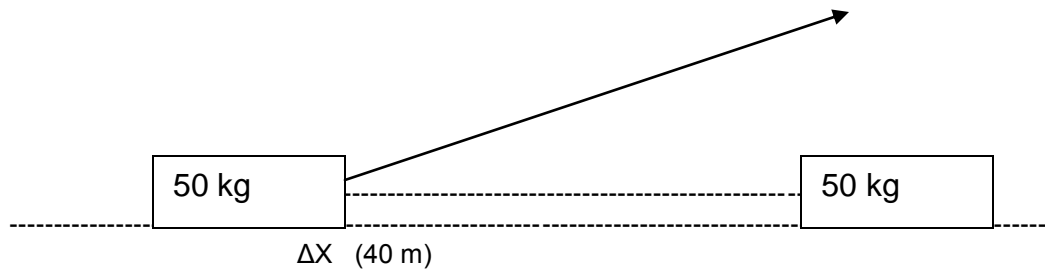
### INSTRUCTIONS

- Four possible answers are given for each question;
- Read the question carefully;
- Circle the answer of your choice;
- Evaluate yourself by further making a cross (X) in the appropriate box; and
- Furthermore explain or make comments to support your choice.
- Mark allocation per question:
  - Two (2) marks for each choice;
  - One (1) mark for self-rating;
  - Two (2) marks for comments; and
  - Generally, each question carries five (5) marks except question one (1) that carries nine marks as indicated.

### I CONCEPTUAL DIFFICULTIES IN MECHANICS

#### A. Work , Energy and Power

1. A 50-kg crate is pulled 40 m along a horizontal floor by a constant force exerted by a person,  $F_p = 100$  N, which acts at a  $37^\circ$  angle as shown in the figure below. The floor is rough and exerts a friction force  $F_f = 50$  N. which ONE of the following is correct for the work done by force  $F_p$  and friction force  $F_f$ .



	WORK DONE BY FORCE $F_p$	WORK DONE BY FRICTION FORCE $F_f$
A	- 3195 J	2000 J
B	2000 J	3195 J
C	3195 J	- 2000 J
D	- 2000 J	- 3195 J

(2)

(2)

[4]

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

$F_p$  \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_ (2)

$F_f$  \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_ (2)

2. Consider the statement below:

- I. Work is done on an object when a force displaces the object in the direction of the force.
- II. Mechanical energy of a system is conserved when an external force does no work on the system.
- III. The work done on an object by a net force is equal to the kinetic energy of the object.

Which of the above statements is/are CORRECT?

- A. Only I
  - B. I and II only
  - C. II and III only
  - D. I, II and III
- (2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_ (2)

- A.  $W$   
B.  $2W$   
C.  $3W$   
D.  $4W$

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

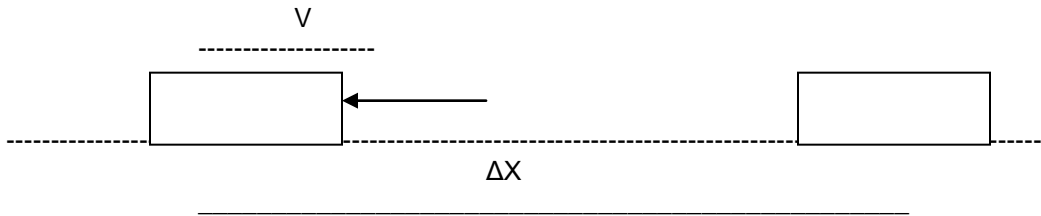
(2)

- A.  $\frac{1}{4} E$   
B.  $\frac{1}{2} E$   
C.  $2 E$   
D.  $4 E$

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(2)

5. Consider the block sliding along a surface as shown in the figure below. The only unbalanced force acting on it is the frictional force  $f$ .



Which ONE of the following equations can be used to find the work done by the frictional force on the object?

- A.  $W_f = f \Delta x \sin 0^\circ$
  - B.  $W_f = f \Delta x \cos 180^\circ$
  - C.  $W_f = f \Delta x \cos 0^\circ$
  - D.  $W_f = f \Delta x \cos 90^\circ$
- (2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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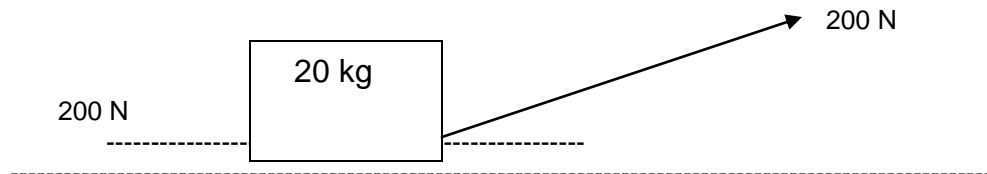
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(2)

6. Two forces, each of magnitude 200 N, are simultaneously applied to a crate at rest on a horizontal surface as shown in the diagram below. Ignore the effects of friction.



Work will be done by the net force on the crate because the crate will ...

- A. be lifted off the surface.
- B. accelerate to the left.
- C. accelerate to the right.
- D. Remain at rest.

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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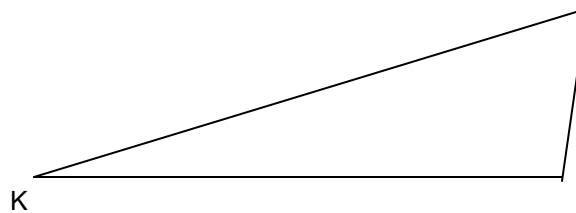
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(2)

**B. Motion on inclined surface**

7. Consider a truck accelerating up a rough constant slope inclined at  $20^\circ$  to the horizontal.



Which ONE of the following forces does no work in moving the truck from point **K** to point **P**. The ...

- E. normal force acting on the truck.
  - F. frictional force acting on the truck.
  - G. force of the earth acting on the truck.
  - H. force exerted by the engine on the truck.
- (2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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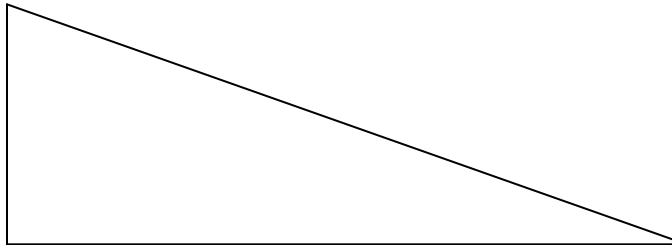
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(2)

6. 8. A person skis down a 20 m long snow slope which makes an angle of  $25^\circ$  with the horizontal.

The total mass of the skier and skis is 50 kg. There is a constant frictional force of 60 N opposing the skier's motion. The speed of the skier as he/she descends from the top of the slope is  $2,5 \text{ m.s}^{-1}$ .

$$V_i = 2,5 \text{ m.s}^{-1}$$



The magnitude of the net force parallel to the slope experienced by the person is

- A. -207,08 N
- B. -147,08 N
- C. 147,08 N
- D. 207,08 N

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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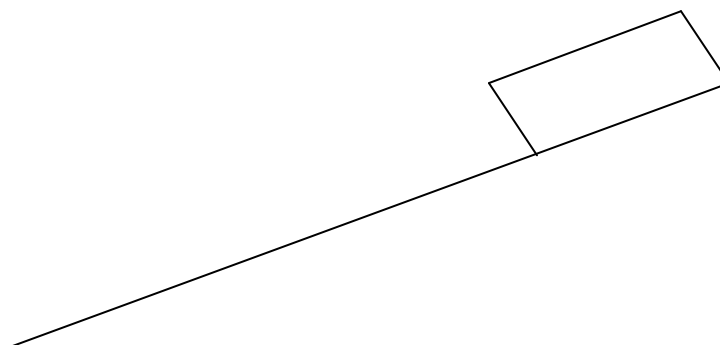
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(2)

QUESTIONS 9, 10, 11 AND 12 ARE BASED ON THE STATEMENT AND THE FIGURE IN QUESTION 9 BELOW.

7. 9. A box of mass 60 kg starts from rest at height  $h$  and slides down a rough slope of length 10 m, which makes an angle of  $25^\circ$  with the horizontal. It undergoes a constant acceleration of magnitude  $2 \text{ m.s}^{-2}$  while sliding down the slope.



The box reaches the bottom of the slope. The kinetic energy of the box is

- A. -1 200 J
- B. 2 485 J
- C. -1 285 J
- D. 1 200 J

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

8. 10. The work done on the box by the gravitational force is

- A. -1 200 J  
B. 2 485 J  
C. -1285 J  
D. 1 200J

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

[illegible]

9. 11. The work done on the box by the frictional force is

- A. -1 200 J  
B. 2485 J  
C. -1285 J  
D. 1 200 J

(2)

Just a blind guess	Not very confident	Fairly confident	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

(2)

10. 12. The magnitude of the frictional force acting on the box is

- A. -128, 5 N  
B. 128, 5 N  
C. 1 200 N  
D. -1 200 N

(2)





Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

12. 14. The kinetic energy of the cyclist at position A is

- A. 2 750 J
- B. 646, 8 J
- C. -144 J
- D. 1 959,2 J

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

13. 15. The kinetic energy of the cyclist at the top of the ramp (position B) is

- A. 2 750 J
- B. 646,8 J
- C. -144 J
- D. 1 959, 2 J

(2)



Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

14. 17. A stone is thrown vertically upwards returns to the thrower's hand after a while. Ignore the effects of air resistance. Which ONE of the following is CORRECT?
- A. The direction of both velocity and acceleration is the same as the stone goes up.
  - B. The acceleration increases as the stone goes up.
  - C. The velocity and acceleration are in the opposite directions as the stone goes up.
  - D. The velocity is constant for the upward motion of the stone.

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

15. 18. A stone is thrown vertically upwards and returns to the thrower's hand after a while. Which ONE of the following velocity-time graphs best represents the motion of the stone

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

19. Jenny throws a tennis ball vertically upward into air. She catches the ball 10 s later at the same height she threw the ball from. Which ONE of the following statements is incorrect with regards to the above situation?

- A. The velocity of the ball decreases as it moves upwards.
  - B. The velocity of the ball is zero when it reaches its maximum height.
  - C. The ball returns to Jenney's hand with the same speed with which she threw the ball upwards.
  - D. The acceleration of the ball as it goes upwards is equal to the acceleration of the ball as it falls downwards but in the opposite direction.
- (2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

20. A stone is dropped from the edge of a cliff. Which ONE of the following graphs best represents the change in kinetic energy of the stone during its fall?

(2)



Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

23. A Book is at rest on a table.

Which of the following do you think is CORRECT?

- A. The table exerts a force upward on the book.
- B. The table does not exert an upward force on the book.
- C. Neither the table nor the book exerts a force.
- D. The book has no weight since it is on the table.

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)



24. A stubborn goat is pushing against a wall.

Which ONE of the following is CORRECT?

- A. The wall exerts a force back on the goat which is larger than the goat's force on the wall.
- B. The wall exerts a force back on the goat which is smaller than the goat's force on the wall.
- C. The wall exerts a force back on the goat which is the same size as the goat's force on the wall.
- D. The wall exerts a force back on the goat which is cannot be compared to the goat's force on the wall.

(2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

25. On a day with no wind, a mosquito lands on top of the Voortrekker Monument in Pretoria.

Which ONE of the following is CORRECT?

- A. The monument and the mosquito each exert a force on the other, but the mosquito exerts a larger force.
- B. Each exerts a force, but the monument exerts a larger force.
- C. Each exerts a force, and the forces are the same size.
- D. Only the monument is exerting a force. (2)

Just a blind guess	Not very sure	Fairly sure	I'm sure, I'm right

(1)

Explain or make comments supporting your choice:

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(2)

THANK YOU VERY MUCH FOR YOUR TIME AND FOR CONTRIBUTING TO THE SUCCESS OF THIS STUDY.

S.P. MCHUNU

UNIVERSITY OF ZULULAND

DOCTORAL CANDIDATE

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PROMOTER: PROF. SN IMENDA

## APPENDIX B

### TRADITIONAL INTERVENTION CURRICULUM DEVELOPMENT

**GRADE:** 12  
**SUBJECT:** Physical Sciences  
**LESSON:** 1  
**TOPIC:** Work **DURATION:** 1 Hour

**AIM:** instil love for Physical Sciences

**OBJECTIVES:** At the end of the lesson, learners should be able to define and calculate work done by a force.

**TEACHING METHOD:** Telling/Lecture Method

**MATTER:**

- 'Work' defined and symbols explained.
- Work done: in symbols:  $W = F \cdot \Delta x \cdot \cos\theta$ .
- **W** is work in joule (**J**)
- **F** is force in newton (**N**);
- The angle (**θ**) is the angle between the force (**F**) and the change in position (displacement) (**ΔX**).
- When the displacement is vertical, **Δy** is used instead of **Δx**.
- **Positive work:** is performed when the component of the force is in the same direction, parallel to the displacement.
- **Negative work:** is performed when the component of the force is in the opposite direction, parallel to the displacement.
- **No work is done** when the force is perpendicular to the displacement ( $\cos\theta = \cos 90^\circ = 0$ ).
- Work done against **gravitational force**
- Work done against **friction**
- $W_f = F_{\text{friction}} \Delta x \cdot \cos 180^\circ$ .
- Examples on Work calculation were given.

**LEARNER ACTIVITIES:** Learners wrote the class work as individuals (Activity 1).

**TEACHING AIDS:** chalk, chalkboard, textbook.

**GRADE:** 12  
**SUBJECT:** Physical Sciences  
**LESSON:** 2  
**TOPIC:** Energy **DURATION:** 1 Hour

**AIM:** To inculcate love for Physical Sciences.

**OBJECTIVES:** At the end of the lesson, learners should be able to define, calculate energy and also give forms of energy.

**TEACHING METHOD:** Telling/Lecture Method

**MATTER:**

- When **work** is done, **energy** is transferred from one object to another or from one place to another or from one type to another.
- **Energy** is thus defined as the ability to do **work**.
- An object that does work has **energy**.
- **Energy** is also a scalar quantity measured in **joule (J)**.
- **Kinetic energy** is the energy an object has as a result of its motion. We use the symbol  $E_k$  or  $K$ , but for examination purposes,  $K$  is preferred ( $K = \frac{1}{2}mv^2$ ). Speed ( $v$ ) is variable.
- **Gravitational Potential energy** is the energy an object has as a result of its position relative to the other objects it interacts with. We use the symbol  $E_p$  or  $U$ , but for examination purposes,  $U$  is preferred ( $U = mgh$ ). Height ( $h$ ) is a variable.
- The **sum** of kinetic ( $K$ ) and gravitational potential energy ( $U$ ) is called **mechanical energy**.
- If no external forces act on an object and there is no energy loss due to friction, then the mechanical energy of the object or system will remain constant.
- Examples on energy calculations were given.

**LEARNER ACTIVITIES:** Learners wrote the class work as individuals (Activity 2).

**TEACHING AIDS:** chalk, chalkboard, textbook.

**GRADE:** 12  
**SUBJECT:** Physical Sciences  
**LESSON:** 3  
**TOPIC:** Energy Principles                      **DURATION:** 1 Hour

**AIM:** To instil love for Physical Sciences.

**OBJECTIVES:** At the end of the lesson, learners should be able to state the Law of Conservation of Energy, the Principle of Conservation of Mechanical Energy and work-energy theorem. Learners should also be able to apply these principles in solving mechanics problems.

**TEACHING METHOD:** Telling/Lecture Method

**MATTER:**

- The following law and principle was stated and applied:
  - Law of Conservation of Energy; and
  - Principle of Conservation of Mechanical Energy.
- A **closed system** means that only the gravitational force acts on an object and there are no other external (non-conservative) forces.
- The amount of **gravitational potential energy,  $U = mgh$** , which is transferred to the object, is equal to the work done in order to move the object against the gravitational force acting vertically on the object.
- The greater the potential energy of the object, the greater is its ability to do work.
- The relationship between work done on an object by  $F_{\text{net}}$  and the change in object's  $K$  is called the **work-kinetic energy principles (theorem)** and is described as follows: "the work done on an object by a net (resultant) force acting on it is equal to the change in kinetic energy of the object.
- More examples based on energy principles were done.
- Whenever a frictional force is involved, this work-energy theorem principle must be used.

**LEARNER ACTIVITIES:** Learners wrote the class work as individuals (Activity 3).

**TEACHING AIDS:** chalk, chalkboard, textbook.

**GRADE:** 12  
**SUBJECT:** Physical Sciences  
**LESSON:** 4  
**TOPIC:** Power **DURATION:** 1 Hour

**AIM:** To instil love Physical Sciences.

**OBJECTIVES:** At the end of the lesson, learners should be able to define and calculate power.

**TEACHING METHOD:** Telling/Lecture Method

**MATTER:**

- **Power** is an indication of how fast work is done. By definition, power is the rate at which work is done or of which energy is transferred (expended).  $P = W/\Delta t$ .
- Power, like work and energy, is a scalar quantity and the SI unit of power is watt (W).
- The formula  $P = Fv$  is used to calculate the average power or instantaneous power, if a force causes an object to move at a constant velocity ( $v$ ) and force ( $F$ ) is parallel to the direction of movement.
- If the object (car, truck, etc) travels at constant velocity, then it means that the engine is exerting a force that is equal in magnitude but opposite in direction to the force opposing it (e.g friction, gravity). The equation,  $P = Fv$ , can be derived as follows:  $P = W/\Delta t$ , but  $W = F\Delta x$ , therefore  $P = F\Delta x/\Delta t$ , and  $x/t = v$ , therefore  $P = Fv$ .
- More examples based on power were given.

**LEARNER ACTIVITIES:** Learners wrote the class work as individuals (Activity 3).

**TEACHING AIDS:** chalk, chalkboard, textbook.

**GRADE:** 12  
**SUBJECT:** Physical Sciences  
**LESSON:** 5  
**TOPIC:** Projectile Motion                      **DURATION:** 1 Hour

**AIM:** To instil love for Physical Sciences

**OBJECTIVE:** At the end of the lesson, learners should be able to describe the motion of projectiles (e.g. a ball bouncing, thrown vertically upwards and thrown vertically downwards).

**TEACHING METHOD:** Telling/Lecture Method

**MATTER:**

- **Free fall** is the uninterrupted motion of an object in the absence of air friction (resistance) where only gravitational force influences the object.
- The **weight** of an object can be expressed as the gravitational force of attraction that the earth has on an object and is directed downwards towards the centre of the earth.
- **Gravitational acceleration** is the constant acceleration that a free falling object experiences due to gravitational attraction of the earth in the absence of air resistance, whether the object is moving upwards or downwards. The symbol is  $g$  and the value is  $9,8 \text{ m.s}^{-2}$  downwards.
- A projectile is an object (e.g. stone, ball or bullet) that is given an initial velocity by dropping, shooting, throwing or projecting (launching) it, and where the only other force acting on it is due to the force of gravity.
- Projectiles in motion:
  - Have zero velocity at their greatest height;
  - Take the same time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch; and
  - Can have their motion described by a simple set of equations for the upward and downward motion.

**LEARNER ACTIVITIES:** Learners wrote the class work as individuals (Activity 5).

**TEACHING AIDS:** chalk, chalkboard, textbook.

**GRADE:** 12  
**SUBJECT:** Physical Sciences  
**LESSON:** 6  
**TOPIC:** Projectile Motion      **DURATION:** 1 Hour

**AIM:** To instil love for Physical Sciences

**OBJECTIVES:** At the end of the lesson, learners should be able to draw and interpret graphs of position-time, velocity time and acceleration-time. Learners should also be able to use graphs to determine position, displacement, velocity and acceleration at any time.

**TEACHING METHOD:** Telling/Lecture Method

**MATTER:**

- Graphs of position-time, velocity-time and acceleration-time were drawn, interpreted and discussed with learners.
- Graphs were used to determine position, displacement, velocity and acceleration at any time.
- Equations used in calculations of projectile motion:

- $V_f = V_i + a.\Delta t$
- $V_f^2 = V_i^2 + 2a\Delta y$
- $\Delta y = v\Delta t + \frac{1}{2} a\Delta t^2$
- $\Delta y = \frac{v_1 + v_2}{2} .\Delta t$

- Each of the above symbols were explained and their SI units were given.

**LEARNER ACTIVITIES:** Learners wrote the class work as individuals (Activity 6).

**TEACHING AIDS:** chalk, chalkboard, textbook.



**GRADE:** 12  
**SUBJECT:** Physical Sciences  
**LESSON:** 7  
**TOPIC:** Force and Newton's Laws **DURATION:** 1 Hour

**AIM:** To instil love for Physical Sciences

**OBJECTIVE:** At the end of the lesson, learners should be able to differentiate between contact and non-contact forces and also give examples of these forces. Learners should also be able to state Newton's Laws and apply them in solving mechanics problems.

**TEACHING METHOD:** Telling/Lecture Method

**MATTER:**

- **Contact forces** are exerted by objects in contact, as push or pull, friction forces and normal forces.
- **Non-contact forces** are forces like magnetic forces, electrostatic forces and gravitational forces where objects are not in contact with each other but still exerting a force on each other.
- Newton's First and Third Laws were contrasted.
- Newton's Third Law states that when pairs of objects interact they exert forces on each other. These forces are equal in size and point in opposite directions.
- According to **Newton's Third Law** of motion a **Force Pair**:
  - Will be the same size but in opposite directions;
  - Work along the same line;
  - Exert a force on two objects;
  - Will be of the same force type; and
  - Will be exerted at the same time.
- More examples were given on force pairs.

**LEARNER ACTIVITIES:** Learners wrote the class work as individuals (Activity 7).

**TEACHING AIDS:** chalk, chalkboard, textbook.

















## APPENDIX E TBM Scores

### E 1: TBM (Pre-Test) Scores for All Four Groups

Intervention Groups	Traditional Group	OBE Group	Blended Group	Comparison Group
Scores	43	39	63	55
	43	48	46	49
	45	39	49	39
	43	55	58	42
	45	55	48	55
	39	36	43	45
	45	61	26	51
	49	51	54	42
	47	41	41	67
	49	49	48	44
	45	53	47	48
	49	71	32	47
	47	55	59	46
	43	51	32	55
	41	69	37	48
	44	51	59	40
	53	53	53	55
	55	51	50	65
	51	41	69	42
	55	53	49	51
	43	34	55	73
	55	49	55	68
	51	52	49	49
	55	47	49	47
	55	45	53	47
	55	44	43	44
	48	51	61	49
	55	47	46	43
	55	40	58	60
	47	42	48	49
	53	33	63	43
	37	46	41	53
	51	38	36	50
	57	66	47	39
	47	50	59	40
N	35	35	35	35
Mean	48,43	48,74	49,31	49,71
Variance				

## E 2: Traditional Group Pre- and Post-Test Scores

Intervention Group	Traditional Group	
BMT	Pre-test	Post-test
Scores	43	71
	43	61
	45	57
	43	63
	45	57
	39	61
	45	73
	49	59
	47	65
	49	67
	45	59
	49	66
	47	63
	43	51
	41	73
	44	68
	53	65
	55	60
	51	62
	55	68
	43	59
	55	57
	51	68
	55	58
	55	61
	55	63
	48	64
	55	62
	55	69
	47	61
	53	68
	37	56
	51	57
	57	56
	47	57
N	35	35
Mean	48,43	62,42
Variance		

### E 3: OBE Group Pre- and Post-Test Scores

Intervention Group	OBE Group	
BMT	Pre-test	Post-test
Scores	39	74
	48	63
	39	60
	55	80
	55	67
	36	77
	61	73
	51	75
	41	77
	49	75
	53	71
	71	73
	55	87
	51	64
	69	75
	51	79
	53	77
	51	70
	41	71
	53	70
	34	69
	49	73
	52	73
	47	70
	45	63
	44	70
	51	67
	47	65
	40	68
	42	67
	33	77
	46	77
	38	87
	66	76
	50	73
N	35	35
Mean	48,74	72,37
Variance		

#### E 4: Blended Group Pre- and Post-Test Scores

Intervention Group	Blended Group	
	Pre-test	Post-test
Scores	63 46 49 58 48 43 26 54 41 48 47 32 59 32 37 59 53 50 69 49 55 55 49 49 53 43 61 46 58 48 63 41 36 47 59	106 77 95 97 86 104 98 93 96 111 120 83 94 88 101 84 81 97 98 83 89 108 88 90 88 83 92 110 80 111 109 78 88 116 78
N	35	35
Mean	49,31	94,28
Variance		

### E 5: Comparison Group Pre- and Post-Test Scores

Intervention Group	Comparison Group	
	Pre-test	Post-test
Scores	55 49 39 42 55 45 51 42 67 44 48 47 46 55 48 40 55 65 42 51 73 68 49 47 47 44 49 43 60 49 43 53 50 39 40	34 35 62 60 64 35 49 76 58 58 42 35 61 69 61 48 41 44 36 35 40 42 42 55 44 64 61 54 41 64 58 58 46 49 55
N	35	35
Mean	49,71	50,74
Variance		

## E 6: BMT (Post-Test) Scores

Intervention Groups	Traditional Group	OBE Group	Blended Group
Scores	71	74	106
	61	63	77
	57	60	95
	63	80	97
	57	67	86
	61	77	104
	73	73	98
	59	75	93
	65	77	96
	67	75	111
	59	71	120
	66	73	83
	63	87	94
	51	64	88
	73	75	101
	68	79	84
	65	77	81
	60	70	97
	62	71	98
	68	70	83
	59	69	89
	57	73	108
	68	73	88
	58	70	90
	61	63	88
	63	70	83
	64	67	92
	62	65	110
	69	68	80
	61	67	111
	68	77	109
	56	77	78
	57	87	88
	56	76	116
	57	73	78
N	35	35	35
Mean	62,42	72,37	94,28
Variance			

## E 7: Traditional Group versus OBE Group Scores

Intervention Group	Traditional vs OBE approach	
BMT	Post-test	Post-test
Scores	71	74
	61	63
	57	60
	63	80
	57	67
	61	77
	73	73
	59	75
	65	77
	67	75
	59	71
	66	73
	63	87
	51	64
	73	75
	68	79
	65	77
	60	70
	62	71
	68	70
	59	69
	57	73
	68	73
	58	70
	61	63
	63	70
	64	67
	62	65
	69	68
	61	67
	68	77
	56	77
	57	87
	56	76
	57	73
N	35	35
Mean	62,42	72,37
Variance		

## E 8: Traditional Group versus Blended Group Scores

Intervention Group	Traditional vs Blended approach	
BMT	Post-test	Post-test
Scores	71	106
	61	77
	57	95
	63	97
	57	86
	61	104
	73	98
	59	93
	65	96
	67	111
	59	120
	66	83
	63	94
	51	88
	73	101
	68	84
	65	81
	60	97
	62	98
	68	83
	59	89
	57	108
	68	88
	58	90
	61	88
	63	83
	64	92
	62	110
	69	80
	61	111
	68	109
	56	78
	57	88
	56	116
	57	78
N	35	35
Mean	62,42	94,28
Variance		



### E 9: OBE Group versus Blended Group Scores

Intervention Group	OBE vs Blended approach	
BMT	Post-test	Post-test
Scores	74	106
	63	77
	60	95
	80	97
	67	86
	77	104
	73	98
	75	93
	77	96
	75	111
	71	120
	73	83
	87	94
	64	88
	75	101
	79	84
	77	81
	70	97
	71	98
	70	83
	69	89
	73	108
	73	88
	70	90
	63	88
	70	83
	67	92
	65	110
	68	80
	67	111
	77	109
	77	78
	87	88
	76	116
	73	78
N	35	35
Mean	72,37	94,28
Variance		

## **APPENDIX F     CORRESPONDENCE**

### **CORRESPONDENCE (Between the Researcher and Education Officials)**

**CORRESPONDENCE TO :**

- (F1) Empangeni Education District Manager**
- (F2) Lower Umfolozi Circuit Manager**
- (F3) Richards Bay Ward Manager**
- (F4) School Principals**

## **APPENDIX F 1: LETTER TO EMPANGENI EDUCATION DISTRICT**

PO Box 2047  
EMPANGENI  
3880

22 JANUARY 2010

THE DISTRICT MANAGER

EMPANGENI EDUCATION DISTRICT  
P/BAG X 20104  
EMPANGENI  
3880

Dear Sir / Madam

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I am presently registered for a D.Ed Degree in the faculty of education at the University of Zululand.

I am conducting a research study entitled: "Alleviating Conceptual Difficulties and Alternative Conceptions in mechanics."

I am requesting access to some of the schools in your circuit, in order to carry out an investigation regarding the above-mentioned topic. I wish to administer a questionnaire, pre-test and post-test to Grade 12 Physical Sciences learners from schools selected randomly in the district.

You are assured that the study will not in any way interfere with the normal running of the school. Copies of the questionnaire and test are attached. I hope they meet your approval. The names of the schools will be strictly treated as confidential, but the findings of this research can be forwarded to your office should you wish so.

Your permission to conduct research in this circuit will be highly appreciated.

Yours faithfully

S P Mchunu (Mr)

## **APPENDIX F 2: LETTER TO LOWER UMFOLOZI CIRCUIT MANAGER**

PO Box 2047  
EMPANGENI  
3880

22 JANUARY 2010

THE CIRCUIT MANAGER

LOWER UMFOLOZI CIRCUIT  
P/BAG X 14  
EMPANGENI RAIL  
3910

Dear Sir

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I am presently registered for a D.Ed Degree in the faculty of education at the University of Zululand.

I am conducting a research study entitled: "Alleviating Alternative Conceptions and Conceptual Difficulties in Mechanics."

I am requesting access to some of the schools in your circuit, in order to carry out an investigation regarding the above-mentioned topic. I wish to administer a questionnaire, pre-test and post-test to Grade 12 Physical Sciences Learners from schools selected randomly in the your circuit.

You are assured that the study will not in any way interfere with the normal running of the school.

Copies of the questionnaire and the test are attached. I hope they meet your approval. The names of the schools will be strictly treated as confidential, but the findings of this research can be forwarded to your office should you wish so.

Your permission to conduct research in this circuit will be highly appreciated.

Yours faithfully

S P Mchunu

## **APPENDIX F 3: LETTER TO RICHARDS BAY WARD MANAGER**

P O Box 2047  
EMPANGENI  
3880

22 January 2010

THE WARD MANAGER

Dr VE Skhosana

LOWER UMFOLOZI CIRCUIT  
P/BAG X 14  
EMPANGENI RAIL  
3910

DEAR Sir

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I am presently registered for a D.Ed Degree in the faculty of education at the University of Zululand. I am conducting a research study entitled: "Alleviating Alternative Conceptions and Conceptual Difficulties in Mechanics".

I am requesting access to some of the schools in your ward, in order to carry out an investigation regarding the above-mentioned topic. I wish to administer a questionnaire, pre-test and post-test to Grade 12 Physical Sciences Learners from schools selected randomly.

You are assured that the study will not in any way interfere with the normal running of the school. Copies of the questionnaire and the test are attached. I hope they meet your approval. The names of the schools will be strictly treated as confidential, but the findings of this research can be forwarded to your office should you wish so.

Your permission to conduct research in this ward will be highly appreciated.

Yours faithfully

---

S P Mchunu (Mr)

## APPENDIX F 4: LETTER TO PRINCIPALS OF SCHOOLS

P.O BOX 2047  
EMPANGENI  
3880

26 July 2010

THE PRINCIPAL

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

DEAR Sir

### RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I am presently registered for a D.Ed Degree in the faculty of education at the University of Zululand. I am conducting a research study entitled: "Alleviating Alternative Conceptions and Conceptual Difficulties in Mechanics."

I hereby seek your permission to administer a questionnaire to grade 12 Physical Science learners. Copies of the questionnaire and the test are attached. I hope they meet your approval.

The information to be obtained will be strictly treated as confidential and will be used for the benefit of the school. You are also assured that the study will not in any way interfere with the normal running of the school.

I hope this study will make a meaningful contribution towards the teaching and learning of Physical Science in the FET band.

Your permission to conduct research in this school will be highly appreciated.

In anticipation, thank you for your kind consideration.

Yours faithfully

\_\_\_\_\_  
S. P. Mchunu (Mr)

## APPENDIX C

### OBE INTERVENTION CURRICULUM DEVELOPMENT

<b>Subject:</b> Physical Sciences <b>Lesson:</b> # 1 <b>Duration:</b> 3 hrs		<b>Grade:</b> 12 <b>No. of Activities:</b> 3 <b>Week / Day:</b> 1 – 3	
<b>Context:</b> Movement. Transport, Road accidents			
<b>Core Content (SKVs):</b> Mechanics			
	<b>Activity 1:</b> 1 hour	<b>Activity 2:</b> 1 hour	<b>Activity 3:</b> 1 hour
<b>LOs &amp; ASs:</b>	2.1learners define and calculate work done by force.	2.1learners define and calculate energy (K and U) .	2.1learners state energy principles and apply them.
<b>Detail of Activity:</b>	Define work, calculations based on positive and negative work. Giving examples of no work done.	Define energy, simple calculations based on kinetic and potential energy.	State and apply law of conservation of energy, mechanical energy and work-energy theorem.
<b>Teaching Approach(es) And Method(s):</b>	Cooperative group work and class discussion.	Cooperative group work and class discussion.	Cooperative group work and class discussion.
<b>Expanded Opportunities :</b>	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.
<b>Assessment Strategies:</b>	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.
<b>LTSM(Resources):</b>	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.
<b>Teacher Reflection:</b>	What worked, what needs improvement?	What worked, what needs improvement?	What worked, what needs improvement?

<b>Subject:</b> Physical Sciences <b>Lesson:</b> # 2 <b>Duration:</b> 3 hrs		<b>Grade:</b> 12 <b>No. of Activities:</b> 3 <b>Week / Date:</b> 4 – 6	
<b>Context:</b> Movement. Transport, Road accidents			
<b>Core Content (SKVs):</b> Mechanics			
	<b>Activity 1:</b> 1 hour	<b>Activity 2:</b> 1 hour	<b>Activity 3:</b> 1 hour
<b>LOs &amp; ASs:</b>	2.1learners define and calculate power.	2.1learners describe the motion of a projectile.	2.1learners draw and interpret graphs
<b>Detail of Activity:</b>	Define work, do simple calculations based on power	Describe motion of a projectile, e.g. ball bouncing, thrown vertically upwards or downwards.	Draw and interpret graphs of position-time, velocity-time and acceleration-time.
<b>Teaching Approach(es) And Method(s):</b>	Cooperative group work and class discussion.	Cooperative group work and class discussion.	Cooperative group work and class discussion.
<b>Expanded Opportunities :</b>	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.
<b>Assessment Strategies:</b>	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.
<b>LTSM(Resources):</b>	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.
<b>Teacher Reflection:</b>	What worked, what needs improvement?	What worked, what needs improvement?	What worked, what needs improvement?



<b>Subject:</b> Physical Sciences <b>Lesson:</b> # 3 <b>Duration:</b> 3 hrs		<b>Grade:</b> 12 <b>No. of Activities:</b> 3 <b>Week / Date:</b> 7 – 9	
<b>Context:</b> Movement. Transport, Road accidents			
<b>Core Content (SKVs):</b> Mechanics			
	<b>Activity 1:</b> 1 hour	<b>Activity 2:</b> 1 hour	<b>Activity 3:</b> 1 hour
<b>LOs &amp; ASs:</b>	2.1learners do basic calculations based on graphs.	2.1learners state Newton's laws.	2.1learners draw free-body diagram.
<b>Detail of Activity:</b>	Use graphs to determine position, displacement, velocity and acceleration at any time.	Distinction between contact and non-contact forces. State and give characteristics of NL3.	1learners differentiate between NL1 and NL3 and draw free-body diagrams.
<b>Teaching Approach(es) And Method(s):</b>	Cooperative group work and class discussion.	Cooperative group work and class discussion.	Cooperative group work and class discussion.
<b>Expanded Opportunities :</b>	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.
<b>Assessment Strategies:</b>	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.
<b>LTSM(Resources):</b>	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.
<b>Teacher Reflection:</b>	What worked, what needs improvement?	What worked, what needs improvement?	What worked, what needs improvement?

## APPENDIX D

### BLENDED INTERVENTION CURRICULUM DEVELOPMENT

<b>Subject:</b> Physical Sciences		<b>Grade:</b> 12	
<b>Lesson:</b> # 1		<b>No. of Activities:</b> 3	
<b>Duration:</b> 3 hrs		<b>Week / Day:</b> 1 – 3	
<b>Context:</b> Movement. Transport, Road accidents			
<b>Core Content (SKVs):</b> Mechanics			
	<b>Activity 1:</b> 1 hour	<b>Activity 2:</b> 1 hour	<b>Activity 3:</b> 1 hour
<b>LOs &amp; ASs:</b>	2.1learners define and calculate work done by force.	2.1learners define and calculate energy (K and U) .	2.1learners state energy principles and apply them.
<b>Detail of Activity:</b>	Define work, calculations based on positive and negative work. Giving examples of no work done.	Define energy, simple calculations based on kinetic and potential energy.	State and apply law of conservation of energy, mechanical energy and work-energy theorem.
<b>Teaching Approach(es) And Method(s):</b>	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.
<b>Expanded Opportunities :</b>	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.
<b>Assessment Strategies:</b>	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.
<b>LTSM(Resour ces):</b>	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.
<b>Teacher Reflection:</b>	What worked, what needs improvement?	What worked, what needs improvement?	What worked, what needs improvement?

<b>Subject:</b> Physical Sciences <b>Lesson:</b> # 2 <b>Duration:</b> 3 hrs		<b>Grade:</b> 12 <b>No. of Activities:</b> 3 <b>Week / Day:</b> 4 – 6	
<b>Context:</b> Movement. Transport, Road accidents			
<b>Core Content (SKVs):</b> Mechanics			
	<b>Activity 1:</b> 1 hour	<b>Activity 2:</b> 1 hour	<b>Activity 3:</b> 1 hour
<b>LOs &amp; ASs:</b>	2.1learners define and calculate power.	2.1learners describe the motion of a projectile.	2.1learners draw and interpret graphs
<b>Detail of Activity:</b>	Define work, do simple calculations based on power	Describe motion of a projectile, e.g. ball bouncing, thrown vertically upwards or downwards.	Draw and interpret graphs of position-time, velocity-time and acceleration-time.
<b>Teaching Approach(es) And Method(s):</b>	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.
<b>Expanded Opportunities :</b>	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.
<b>Assessment Strategies:</b>	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.
<b>LTSM(Resources):</b>	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.
<b>Teacher Reflection:</b>	What worked, what needs improvement?	What worked, what needs improvement?	What worked, what needs improvement?

<b>Subject:</b> Physical Sciences		<b>Grade:</b> 12	
<b>Lesson:</b> # 3		<b>No. of Activities:</b> 3	
<b>Duration:</b> 3 hrs		<b>Week / Day:</b> 7 – 9	
<b>Context:</b> Movement. Transport, Road accidents			
<b>Core Content (SKVs):</b> Mechanics			
	<b>Activity 1:</b> 1 hour	<b>Activity 2:</b> 1 hour	<b>Activity 3:</b> 1 hour
<b>LOs &amp; ASs:</b>	2.1learners do basic calculations based on graphs.	2.1learners state Newton's laws.	2.1learners draw free-body diagram.
<b>Detail of Activity:</b>	Use graphs to determine position, displacement, velocity and acceleration at any time.	Distinction between contact and non-contact forces. State and give characteristics of NL3.	1learners differentiate between NL1 and NL3 and draw free-body diagrams.
<b>Teaching Approach(es) And Method(s):</b>	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.	Narrating, Lecture, Cooperative group work and class discussion. Worksheets completion.
<b>Expanded Opportunities :</b>	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.
<b>Assessment Strategies:</b>	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.
<b>LTSM(Resources):</b>	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.	Textbooks, worksheets, chalk, chalkboard and OHP.
<b>Teacher Reflection:</b>	What worked, what needs improvement?	What worked, what needs improvement?	What worked, what needs improvement?

<b>Subject:</b> Physical Sciences <b>Lesson:</b> # 4 <b>Duration:</b> 3 hrs		<b>Grade:</b> 12 <b>No. of Activities:</b> 3 <b>Week / Day:</b> 10 - 12	
<b>Context:</b> Movement. Transport, Road accidents			
<b>Core Content (SKVs):</b> Mechanics			
	<b>Activity 1:</b> 1 hour	<b>Activity 2:</b> 1 hour	<b>Activity 3:</b> 1 hour
<b>LOs &amp; ASs:</b>	2.1learners observe a trajectory of the projectile motion.	2.1learners watch and observe animations.	Learners solve work and energy problems.
<b>Detail of Activity:</b>	Learners observe teacher demonstration of projectile motion using water through the hosepipe.	Learners watch and observe animations through data projector.	Learners given miscellaneous problems based on work and energy, especially motion on incline surfaces.
<b>Teaching Approach(es) And Method(s):</b>	Narrating, fieldwork, game Lecture, Demonstration, Cooperative group work and class discussion. Worksheets completion.	Teaching-learning, Lecture, and class discussion. Worksheets completion. Question and answer method.	Question and answer, Cooperative group work, worksheets completion.
<b>Expanded Opportunities :</b>	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.	Allow learners to share information in groups or in pairs. Allow fast learners to continue with other activities.
<b>Assessment Strategies:</b>	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.	Learners give class work. Peer assessment with educator facilitating the assessment.
<b>LTSM(Resources):</b>	Water, Hosepipe, Textbooks, worksheets, chalk, chalkboard.	Data projector, worksheets, chalk, chalkboard and .	Textbooks, worksheets, chalk, chalkboard.
<b>Teacher Reflection:</b>	What worked, what needs improvement?	What worked, what needs improvement?	What worked, what needs improvement?