

TABLE OF CONTENTS

CHAPTER	CONTENT	PAGE
	Acknowledgements	ii
	Abstract	iii
	Abstrak	v
	Table of Contents	vii
	List of Tables	xiv
	List of Figures	xix
CHAPTER 1	INTRODUCTION	
	Introduction	1
	The Malaysian National Education System	4
	The Theory of Cell	6
	Background of the Study	8
	The Statement of Problem	11
	Rational of the Study	14
	Objectives of the Study	17
	Research Questions	17
	Significance of the Study	18
	Limitation of the Study	21
	Definition of Terminologies	23
CHAPTER 2	REVIEW OF LITERATURE	
	Introduction	29
	The Cell as Part of the Living World	30

General Conceptions of Biological Processes Related to the Theory of Cell	32
Movement of Substances across the Plasma Membrane	33
Cell Division	34
Mechanistic Reasoning	38
Definition of Mechanistic Reasoning	39
Mechanistic Reasoning in Biology	43
Discovery of Protein Synthesis	43
Strategies of Mechanistic Reasoning	46
The Value of Mechanistic Reasoning	54
Comparison with Other Reasoning	57
High Achiever and Low Achievers	58
Methodological Aspect in Mechanistic Reasoning	61
Summary	64
CHAPTER 3	CONCEPTUALISATION OF THE STUDY
Introduction	66
Conceptual Framework of the Study	67
Proposed Theoretical Framework	73
Theory of Investigative Learning	73
Internalisation and Re-internalisation	82
Levels of Processing	82
CHAPTER 4	METHODOLOGY
Introduction	88
Preparation of Instrument	89

The Science Test	89
The Incoherency Tests	92
Step 1: Define the Content Domain	95
Step 2: Identify Students' Concepts	95
Step 3: Construction and Validation Of the Instrument	97
Pilot Study	98
Selection of Participants	98
Pilot Study Procedures	99
Analysis of the Incoherency Tests	100
Planning of the Living Cell Tool Tasks	101
Cell Structure and Organisation	103
Movement of Substances across the Plasma Membrane	106
Chemical Composition of the Cell	112
Cell Division	119
Actual Study	126
Students' Mechanistic Reasoning	126
Selection of participants	126
Procedures for the Data Collection Using the Living Cell Tool	129
Infusion of Mechanistic Reasoning	129
Qualitative Data Collection of Mechanistic Reasoning	131
Validity and Reliability	134
CHAPTER FIVE	ANALYSIS OF MECHANISTIC REASONING
Introduction	138
Analysis of Students' Mechanistic Reasoning	138

Step 1: Dividing the Data According to the Principle for the Theory of Cell	144
Step 2: Coding the Materials	146
Step 3: Identifying the Links	148
Step 4: Converting the Links into Configurations	151
Step 5: Exploring the Types of Configurations	152
Step 6: Generating chaining	157
Step 7: Interpreting Mechanistic Reasoning	159
Type I Simple Mechanistic Reasoning	160
Type II Simple Mechanistic Reasoning	161
Type I Complex Mechanistic Reasoning	163
Type II Complex Mechanistic Reasoning	165
Summary of Students' Mechanistic Reasoning	168
Analysis of Students' Representations for the Theory of Cell	169
Representations Categorised as the Intuitive Representations	170
Representations Categorised as the Assimilated Representations	170
Representations Categorised as the Transformational Representations	173
Representations Categorised as the Misinterpreted Representations	174
Summary	174

CHAPTER SIX FINDINGS AND DISCUSSIONS

Introduction	175
Students' Mechanistic Reasoning	177
High and Low Achieving Students' Mechanistic Reasoning	179
H1's Mechanistic Reasoning for the	180

Theory of Cell	
H2's Mechanistic Reasoning for the Theory of Cell	190
H3's Mechanistic Reasoning for the Theory of Cell	201
H4's Mechanistic Reasoning for the Theory of Cell	211
L1, L2 and L4's Mechanistic Reasoning for the Theory of Cell	221
L3 and L5's Mechanistic Reasoning for the Theory of Cell	238
L6's Mechanistic Reasoning for the Theory of Cell	253
Discussion	262
Overall progression of Mechanistic Reasoning From Phase I to Phase IV among High and Low Achieving Students	263
Steady Progression	265
Unstable Progression	270
High and Low Achieving Students' Representations for the Theory of Cell	273
Intuitive Representation	274
Assimilated Representation	275
Elaborated Assimilated Representation within a Phase	277
Elaborated Assimilated Representation across Phases	279
Transformational Representation	282
Misinterpretation Representation	286
Discussion	288
Summary	290

CHAPTER SEVEN CONCLUSIONS AND IMPLICATIOIS OF THE STUDY

Introduction	292
Summary of Findings	293
Implications of the Study	297
Contribution and Significance of the Study for Practice	301
Suggestions for Future Research	302
Conclusion	304

REFERENCES 306

APPENDIX A: The Science Test

APPENDIX B: Curriculum Specification Biology Form Four

APPENDIX C: Grid Specification of Each Incoherency Test

APPENDIX D: The Incoherency Tests

APPENDIX E: The Living Cell Kit

APPENDIX F: Observation protocol

APPENDIX G: Interview Protocol

APPENDIX H: A Set of Example Notes during Classroom Observation , Interviews Transcript and Classroom Observation transcripts

APPENDIX I: Example of H1's Mechanistic Reasoning for the Theory of Cell

APPENDIX J: Example of H1's Mechanistic Reasoning for Each Elements in Each Phase

APPENDIX K: Example of Coding H1's Mechanistic Reasoning by Using Russ's Analytical Framework

APPENDIX L: Example of Converting H1's Mechanistic Reasoning from Russ's Analytical Framework to Types of Links

**APPENDIX M: Example of H1's Configuration in Phase I
Cell Structure and Cell Organisation**

APPENDIX N: Expert's Curriculum Vitae

LIST OF TABLES

NO.	TITLE	PAGE
Table 1.1	Malaysian national education system	5
Table 2.1	List of some important mechanisms in Science	40
Table 2.2	Comparison between mechanistic reasoning and evolutionary reasoning	58
Table 2.3	Summary of methodological aspects in mechanistic reasoning	63
Table 3.1	Students' learning difficulties in biological processes which is related to the Theory of Cell	67
Table 3.2	Previous research in mechanistic reasoning	69
Table 4.1	Expert panels who were involved in the preparation of the three instruments	89
Table 4.2	Science topics in the science test	90
Table 4.3	Example of an item adopted from the literature review and discussed with expert panel A	91
Table 4.4	Example of correction made from earlier version of test	92
Table 4.5	Steps and phase in the development of the four instruments	93
Table 4.6	A student interview for question 1	97
Table 4.7	Reliability using Spearman-Brown for the incoherency test	100
Table 4.8	Percentage of students' selection of the response combination for item 1 in the incoherency test	101
Table 4.9	An example of development of an activity based on one of the preliminary incoherency tests	102
Table 4.10	Incoherencies in students' understanding (Cell structure and cell organisation)	103
Table 4.11	Incoherencies in students' understanding (Movement of substances across the plasma membrane)	107
Table 4.12	Incoherencies in students' understanding (Chemical composition of the cells)	113
Table 4.13	Incoherencies in students' understanding (Cell division)	119

NO.	TITLE	PAGE
Table 4.14	Categorisation of participants according to the two different achievement levels using a standardized examination scale	128
Table 4.15	Time line for infusion and data collection of mechanistic reasoning using the Living Cell Tool	130
Table 4.16	Purpose and method utilized in this present study	132
Table 5.1	The phases and topics in the context of present study	139
Table 5.2	The elements and its respective tasks in the Living Cell Tool in the present research context	144
Table 5.3	Categorisation of students' written tasks according to its respective elements	145
Table 5.4	Russ's et al. (2008) analytical framework in analyzing mechanistic reasoning	147
Table 5.5	Visualising table for H4's mechanistic reasoning for structural element in phase I (cell structure and cell organisation)	149
Table 5.6	Types of configurations and its related characteristics	153
Table 5.7	H1's mechanistic reasoning for structural and organisation elements in phase I	158
Table 5.8	Overall cognitive processing for H1	167
Table 5.9	An example of intuitive representations showed by H2	170
Table 5.10	An example of simple assimilated representations showed by L6	171
Table 5.11	An example of elaborated assimilated representations showed by L3	171
Table 5.12	An example of elaborated assimilated representations showed by L1	172
Table 5.13	An example of transformational representations showed by H1	173
Table 5.14	An example of misinterpreted representations showed by L6	174
Table 6.1	High and low achieving students' demographic data	178
Table 6.2	The phases and elements in the research context	179

NO.	TITLE	PAGE
Table 6.3	H1's mechanistic reasoning for the Theory of Cell	180
Table 6.4	H2's mechanistic reasoning for the Theory of Cell	190
Table 6.5	H3's mechanistic reasoning for the Theory of Cell	201
Table 6.6	H4's mechanistic reasoning for the Theory of Cell	211
Table 6.7	L1's mechanistic reasoning for the Theory of Cell	221
Table 6.8	L2's mechanistic reasoning for the Theory of Cell	223
Table 6.9	L3's mechanistic reasoning for the Theory of Cell	225
Table 6.10	L4's mechanistic reasoning for the Theory of Cell	238
Table 6.11	L5's mechanistic reasoning for the Theory of Cell	240
Table 6.12	L6's mechanistic reasoning for the Theory of Cell	253
Table 6.13	Examples of intuitive representation shown by H2 and L1	274
Table 6.14	Examples of simple assimilated representation shown by H4 and L5	276
Table 6.15	Examples of simple assimilated representation shown by L2 and L4	276
Table 6.16	Examples of elaborated assimilated representation within a phase shown by H4 and L4	277
Table 6.17	Examples of elaborated assimilated representation within a phase shown by H3 and L3	278
Table 6.18	Examples of elaborated assimilated representation across phases shown by H4 and L1	280
Table 6.19	Examples of elaborated assimilated representation within a phase shown by H3	281
Table 6.20	Examples of elaborated assimilated representation within a phase shown by H3	281
Table 6.21	Examples of elaborated assimilated representation within a phase shown by L2 and L4	282
Table 6.22	Examples of transformational representation within a phase shown by H4	283

NO.	TITLE	PAGE
Table 6.23	Examples of transformational representation within a phase shown by H1 and L4	283
Table 6.24	Examples of transformational representation within a phase shown by L1	285
Table 6.25	Examples of transformational representation within a phase shown by H2 and L6	285
Table 6.26	Examples of misinterpreted representation within a phase shown by L6 and L2	286
Table 6.27	Examples of misinterpreted representation within a phase shown by H1 and H2	287

LIST OF FIGURES

NO.	TITLE	PAGE
Figure 1.1	Mechanisms of cancer growth	2
Figure 1.2	Mechanistic reasoning involved in roots grow	12
Figure 2.1	A drawing by student	36
Figure 2.2	Discovery of protein synthesis by Zamecnik and Watson and Crick	45
Figure 2.3	Interaction of ribosomal RNA and transfer RNA	53
Figure 2.4	Mechanisms of duodenal ulcer disease	56
Figure 3.1	Conceptual framework of the study	72
Figure 3.2	The basic structure of the Investigative Learning Theory	74
Figure 3.3	ZPD of high and low achieving students (learners)	76
Figure 3.4	The basic structure of the Investigative Learning Theory in infusing mechanistic reasoning	76
Figure 3.5	Preliminary stages of Investigative Learning Theory	77
Figure 3.6	Internalisation stage in Investigative Learning Theory	78
Figure 3.7	Externalisation stage in Investigative Learning Theory	79
Figure 3.8	Steps in Investigative Learning Theory in the study of mechanistic reasoning	80
Figure 3.9	Steps in Investigative Learning Theory in relating cell structure with the movement of substances across the plasma membrane	81
Figure 3.10	Students' internalisation and –internalisation process as interpreted in Levels of Processing	86
Figure 3.11	Students' Theory of Cell using the <i>Living Cell Kit</i> to infuse mechanistic reasoning as interpreted in Engeström's Investigative Learning Theory, Vygotsky's ZPD and Craik and Lockhart Levels of Processing	87
Figure 4.1	Instrument development flowchart	94
Figure 4.2	Development of a multiple choice with free response item	96

NO.	TITLE	PAGE
Figure 4.3	An example of two-tier test for question 1	97
Figure 4.4	An example of the task (task 2) which was prepared based on students' incoherencies	106
Figure 4.5	An example of the task (task 5) which was prepared based on students' incoherencies	112
Figure 4.6	An example of the task (task 6) which was prepared based on students' incoherencies	118
Figure 4.7	An example of the task (task 7) which was prepared based on students' incoherencies	125
Figure 4.8	Time frames for preparation of instruments, pilot study. Planning for the Living Cell Tool and actual study	127
Figure 4.9	Design of the study	136
Figure 4.10	Overall procedure of the study	137
Figure 5.1	H2's mechanistic reasoning in different tasks for the topic 'Movement of Substance across the Plasma Membrane'	140
Figure 5.2	The connectivity of H3's written tasks across the topics	142
Figure 5.3	The configurations for structural and organisation elements in phase I	158
Figure 5.4	The chaining between the configurations for structural and organisation elements in phase I.	159
Figure 5.5	An example of Type I simple cognitive processing	161
Figure 5.6	An example of Type II simple cognitive processing	162
Figure 5.7	An example of Type I complex cognitive processing	163
Figure 5.8	An example of Type I complex cognitive processing	164
Figure 5.9	An example of Type II complex cognitive processing	166
Figure 5.10	H1's overall change of cognitive processing over time	167
Figure 5.11	Overall steps in analyzing students' mechanistic reasoning	169
Figure 6.1	Students seating arrangement in the laboratory	177
Figure 6.2	H1's type II simple cognitive processing in phase I	182

NO.	TITLE	PAGE
Figure 6.3	H1's type I complex cognitive processing in phase II	185
Figure 6.4	H1's type I complex cognitive processing in phase III	186
Figure 6.5	H1's type I complex cognitive processing in phase IV	187
Figure 6.6	H2's type I simple cognitive processing in phase I	193
Figure 6.7	H2's type II complex cognitive processing in phase II	196
Figure 6.8	H2's type II complex cognitive processing in phase III	198
Figure 6.9	H2's type II complex cognitive processing in phase IV	199
Figure 6.10	H3's type I simple cognitive processing in phase I	203
Figure 6.11	H3's type I complex cognitive processing in phase II, III and IV	206
Figure 6.12	H4's type II simple cognitive processing in phase I	214
Figure 6.13	H4's type I complex cognitive processing in phase II	216
Figure 6.14	H4's type II complex cognitive processing in phase III and IV	218
Figure 6.15	L1, L2 and L4's type I simple cognitive processing in phase I	227
Figure 6.16	L1, L2 and L4's type I complex cognitive processing in phase II	230
Figure 6.17	L1, L2 and L4's type I complex cognitive processing in phase III	233
Figure 6.18	L1, L2 and L4's type I complex cognitive processing in phase IV	235
Figure 6.19	L3 and L5's type II simple cognitive processing in phase I	243
Figure 6.20	L3 and L5's type I complex cognitive processing in phase III	245
Figure 6.21	L3 and L5's type I complex cognitive processing in phase IV	247
Figure 6.22	L3 and L5's type II complex cognitive processing in phase II	251
Figure 6.23	L6's type I simple cognitive processing in phase I	255
Figure 6.24	L6's type I complex cognitive processing in phase II	257
Figure 6.25	L6's type I complex cognitive processing in phase III	259

NO.	TITLE	PAGE
Figure 6.26	L6's type I complex cognitive processing in phase IV	261
Figure 6.27	High achieving students' overall progression of mechanistic reasoning from phase I to phase II	264
Figure 6.28	Low achieving students' overall progression of mechanistic reasoning from phase I to phase II	264
Figure 6.29	A box chart that represents students steady progression from phase I to phase IV	265
Figure 6.30	A summary of the links and chaining that contributed to the steady progression from phase I to phase IV	267
Figure 6.31	A box chart that represents students unstable progression from phase I to phase IV	270
Figure 6.32	A summary of the links and chaining that contributed to the unstable progression from phase I to phase IV	271
Figure 7.10	Flow Preparing the Living Cell Tool	301