THE EFFECTIVENESS OF LEARNING OBJECT-ORIENTED PROGRAMMING CONCEPTS THROUGH ROLE PLAYING GAME AMONG UNDERGRADUATE STUDENTS

WONG YOKE SENG

SULTAN IDRIS EDUCATION UNIVERSITY
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THE EFFECTIVENESS OF LEARNING OBJECT-ORIENTED PROGRAMMING CONCEPTS THROUGH ROLE PLAYING GAME AMONG UNDERGRADUATE STUDENTS

WONG YOKE SENG

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ABSTRACT

This research aims to examine the effectiveness of learning the concept of Object Oriented Programming (OOP) through role-playing games among undergraduate students. A framework on game-based learning (GBL) has been developed and a variety of platform games (computer-based and mobile) titled *Odyssey of Phoenix* have been developed. The development of this game has combined the concept of constructive alignment and design of game elements with appropriate OOP learning content. A total of nine experts were involved in the validity of game design and validity of learning content with each having more than five years of experience. A pilot test was conducted involving 20 students. This study uses a quantitative approach through quasi-experimental pre-test and post-test involving a randomly selected sample of 214 first year undergraduate students in computer science from three institutions of higher learning in Malaysia. A total of 107 people were placed as treatment groups and a total of 107 people were placed as control groups. Data were analyzed using parametric inference statistics such as t-test and variance analysis to test the hypothesis. The t-test results showed that the mean score was high for the treatment group which was 7.36 (M=0.657, SD=9.295) compared to the control group (M=0.731, SD=8.833), t(107)=0.025, p=.0001). The results of the variance analysis showed that the effectiveness of student performance was significant (F=17.6241, p<0.05) for the entire OOP topic. From the score analysis, the mean for the pre-test of the control group was 17.89 while the post-test was 18.61 (difference: 0.72). The mean for the pre-treatment group test was 19.36 while the post-test was 21.99 (difference: 2.63). The results of the scores showed that the performance of the treatment group was better than that of the control group on the overall understanding of the topic. In conclusion, GBL using multi-platform games is found to be very effective as a learning material for a better understanding in learning the concept of OOP. This study implies that the continuous use of GBL can increase its effectiveness in teaching and learning the concept of OOP as a basis before studying the advanced topics of the OOP paradigm.

KEBERKESANAN PEMBELAJARAN KONSEP PENGATURCARAAN BERORIENTASIKAN OBJEK MELALUI PERMAINAN MAIN PERANAN DALAM KALANGAN PELAJAR SARJANA MUDA

ABSTRAK

Kajian ini bertujuan untuk mengkaji keberkesanan pembelajaran konsep Pengaturcaraan Berorientasikan Objek (OOP) melalui permainan main peranan dalam kalangan pelajar sarjana muda. Satu kerangka kerja mengenai pembelajaran berasaskan permainan (PBP) telah dibina dan permainan kepelbagaian platform (berasaskan komputer dan mudah alih) bertajuk of *Odyssey of Phoenix* telah dihasilkan. Pembangunan permainan ini telah menggabungkan konsep penjajaran konstruktif dan rekaan elemen permainan dengan kandungan pembelajaran OOP yang bersesuaian. Seramai sembilan orang pakar terlibat dalam kesahan reka bentuk permainan dan kesahan kandungan pembelajaran dengan masing-masing berpengalaman melebihi lima tahun. Satu ujian rintis telah dijalankan melibatkan 20 orang pelaiar. Kajian ini menggunakan pendekatan kuantitatif melalui ujian kuasi-eksperimen ujian pra dan ujian pasca yang melibatkan bilangan sampel yang dipilih secara rawak seramai 214 orang pelajar tahun satu saijana muda sains komputer dari tiga buah institusi pengajian tinggi di Malaysia. Seramai 107 orang daripadanya diletakkan sebagai kumpulan rawatan dan seramai 107 orang diletakkan sebagai kumpulan kawalan. Data dianalisis menggunakan statistik inferensi parametrik iaitu ujian-t dan analisis varians untuk menguji hipotesis. Keputusan ujian-t menunjukkan min skor adalah tinggi bagi kumpulan rawatan iaitu 7.36 (M=0.657, SD-9.295) berbanding kumpulan kawalan (M=0.731, SD=-8.833), t(107)=0.025, p=.0001). Keputusan analisis varians menunjukkan keberkesanan prestasi pelajar adalah signifikan (F=17.6241, p<0.05) bagi keseluruhan topik OOP. Dari analisis skor, min hagi ujian pra kumpulan kawalan adalah 17.89 manakala ujian pasca adalah 18.61 (perbezaan: 0.72). Min bagi ujian pra kumpulan rawatan adalah 19.36 manakala ujian pasca adalah 21.99 (perbezaan: 2.63). Keputusan skor menunjukkan prestasi kumpulan rawatan adalah lebih baik dari kumpulan kawalan terhadap pemahaman keseluruhan topik. Kesimpulannya, PBP menggunakan permainan berbilang platform didapati sangat berkesan sebagai bahan pembelajaran untuk pemahaman yang baik dalam mempelajari konsep OOP. Kajian ini memberi implikasi bahawa penggunaan PBP secara berterusan dapat meningkatkan keberkesanannya dalam pengajaran dan pembelajaran konsep OOP sebagai asas sebelum mempelajari topik lanjutan paradigma OOP.

TABLE OF CONTENT

	Page
PREPARATION OF ORIGINAL WORK	**ii**
PREPARATION OF THESIS	**iii**
ACKNOWLEDGEMENT	**iv**
ABSTRACT	**v**
ABSTRAK	**vi**
TABLE OF CONTENT	**vii**
LIST OF TABLES	**xiiii**
LIST OF FIGURES	**xvii**
LIST OF ABBREVIATIONS	**xix**
APPENDIX LIST	**xxi**
CHAPTER ONE INTRODUCTION	
1.0 Introduction	1
1.1. Computer programming teaching and learning using Game-Based Learning approach	3
1.1.1. Object-Oriented Programming	3
1.1.2. Problem statement	4
1.1.3. Research gap	7
1.2. Significance of study	9
1.3. Research background	10
1.3.1. Challenges of learning OOP for computer science undergraduates	11
1.3.2. Factors influencing students' learning in OOP	13
1.3.3. Computer and mobile use as teaching and learning tool	14
1.4. Research aim and objectives	19
1.5. Research questions	20
1.6. Research hypotheses	21
1.7. Conceptual framework of research	23

1.8. Scope and limitation of study 27

1.9. Operational definition 29

1.9.1. Object-oriented programming 29

1.9.2. Game-Based Learning approach 30

1.9.3. Serious game model 31

1.9.4. Programming lecturers and students at tertiary level 31

1.9.5. Game developers 31

1.9.6. Key topics of learning OOP 32

1.10. Thesis outline 32

CHAPTER TWO LITERATURE REVIEW

2.0 Introduction 35

2.1. Background of research 36

2.2. GBL approaches 37

2.2.1. Concepts of GBL approaches 38

2.2.2. Design aspects and examples of GBL 41

2.3. Literature on GBL programming learning studies 45

2.4. Existing GBL tool for learning programming 66

2.4.1. Alice 2.0 66

2.4.2. Greenfoot 67

2.4.3. Darwin 68

2.4.4. CodeCombat 69

2.4.5. Analysis of existing GBL tools 70

2.5. Game genres 71

2.5.1. Action game 72

2.5.2. Strategy game 72

2.5.3. Role-Playing game 74

2.5.4. Simulation game 75

2.5.5. Adventure game 76

2.5.6. Selected game genre for proposed game 77

2.6. Game design theories for *Odyssey of Phoenix* Development 77

2.6.1. Constructive Theory 80

2.6.2. Bloom Taxonomy 81

2.6.3. Operant Conditional Theory 81

2.6.4. ARCS Theory of Motivation 82

2.6.5. Hierarchy of Needs Theory 82

2.6.6. Conditions of Learning Theory 83

2.6.7. Summary of relevant theories 84

2.6.8. Computer and mobile game design approach 85

2.7. Conclusion 87

CHAPTER THREE RESEARCH METHODOLOGY

3.0 Introduction 88

3.1. General research design 89

3.1.1. Research methodology for proposed *Odyssey of Phoenix* development 90

3.1.2. Proposed GBL conceptual framework 94

3.1.3. Research experimentation for Proposed *Odyssey of Phoenix* development 105

3.2. Dependent variables of *Odyssey of Phoenix* testing for OOP 106

3.2.1. Fundamental of Object-Oriented Programming 106

3.2.2. Encapsulation 107

3.2.3. Inheritance 108

3.2.4. Polymorphism 108

3.3. Independent variables of *Odyssey of Phoenix* testing for OOP 109

3.3.1. GBL factor 109

3.3.2. Academician/ lecturer/ subject expert 110

3.3.3. Game designer 110

3.3.4. Age issue 111

3.3.5. Gender issue 111

3.3.6. Learning environment 112

3.4. Programming syllabus at different University Colleges 112

3.4.1. Taylor University 113

3.4.2. KDU University College 114

3.4.3. Tunku Abdul Rahman University College 115

3.4.4. Summary of finding 116

3.5. Sampling requirement 116

3.6. Research instrument 117

3.6.1. Pre-test and post-test designs 117

3.6.2. Validation assessment questionnaire 118

3.7. Data collection and analysis procedure 122

3.7.1. Data analysis 124

3.8. Testing of *Odyssey of Phoenix* 125

3.8.1. Reliability testing 126

3.8.2. Alpha testing 126

3.8.3. Pilot testing and actual testing 127

CHAPTER FOUR GAME DESIGN, DEVELOPMENT AND VALIDATION OF *ODYSSEY OF PHOENIX*

4.0 Introduction 128

4.1. GBL driven framework with game development approach 129

4.1.1. Introduction 129

4.1.2. Design Model of Game-Based Learning Game - *Odyssey of Phoenix* 131

4.2. Analysis phase 135

4.2.1. Content knowledge analysis 136

4.2.2. Learning syllabus, objective and learning outcome from various universities and colleges 137

4.3. Design phase 139

4.3.1. Constructive alignment with *Odyssey of Phoenix* 140

4.3.2. Game related design 143

4.4. Development phase 147

4.4.1. Game storyline 148

4.4.2. Gameplay guide for game worlds 153

4.4.3. Narrative design 155

4.4.4. Installation of *Odyssey of Phoenix* 174

4.5. Evaluation phase 175

4.6. Validation of proposed game 175

4.6.1. Result of GBL Game evaluation by experts 176

4.6.2. Result of Constructive Alignment of GBL game with proposed mechanics 180

4.6.3. Result of pre-test and post-test validation 182

4.6.4. Result of GBL Game framework validation 183

4.7. Pilot testing of proposed game 188

4.8. Conclusion 192

CHAPTER FIVE DATA ANALYSIS AND DISCUSSION

5.0 Introduction 193

5.1. Results of GBL game effectiveness evaluation on student performance 194

5.1.1. Levene Test analysis 194

5.1.2. Experimental group 195

5.1.3. Control group 200

5.1.4. ANOVA analysis 204

5.1.5. Results of GBL game effectiveness evaluation on student understanding of OOP topics 206

5.1.6. Results of usability of GBL game 257

5.1.7. Results of interview sessions 263

5.2. Overall hypothesis result 268

5.3. Summary 269

CHAPTER SIX DISCUSSION, RECOMMENDATION AND CONCLUSION

6.0 Introduction 270

6.1. Discussions 271

6.1.1. Research questions 271

6.1.2. Research hypotheses 277

6.1.3. Contributions 279

6.1.4. Research implication 282

6.2. Future work 284

6.2.1. GBL framework 284

6.2.2. GBL game – *Odyssey of Phoenix* 285

6.3. Conclusion 287

REFERENCES 288

APPENDICES

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LIST OF TABLES

Table 1.1	Analysis of Existing GBL Research	18
Table 2.1	Summary of Four Existing Games that Aims to Learn Programming	69
Table 2.2	Learning Theories Applied in OOP Learning Game Development, Their Definitions and Impacts on GBL Design	83
Table 3.1	Pre-Test and Post-Test for Group Studies	89
Table 3.2	Experimental setup for OOP Learning Testing for Each University College	104
Table 3.3	Total Guided and Independent Learning Scores for Taylor University	112
Table 3.4	Total Guided and Independent Learning Scores for KDU University College	114
Table 3.5	Total Guided and Independent Learning Scores for TARUC	115
Table 3.6	Data Collection Procedure Expressed in Different Phases	122
Table 3.7	Data Collection for Control and Experimental Groups	123
Table 3.8	Analysis of Data Collection for Control and Experimental Groups	124
Table 4.1	Sequential Phase for *Odyssey of Phoenix* Development	129
Table 4.2	OOP-Related Module Structure from Different Universities	137
Table 4.3	Constructive Alignment of Quest Task to Outcome	140
Table 4.4	Constructive Alignment of Crafting Process to Outcome	141
Table 4.5	Constructive Alignment of Multi Choice Question to Outcome	142
Table 4.6	Design of Game Characters in *Odyssey of Phoenix*	146
Table 4.7	HEWC Results for the Evaluation of GBL Game	175
Table 4.8	Rating Scale and Severity Description	176
Table 4.9	Percentage Assigned for Each Heuristic	176
Table 4.10	Sample Calculation for Each Component	178
Table 4.11	Overall Data Analysis for Each Component in HEWC	178

Table 4.12	Scoring System Table for Constructive Alignment Study	179
Table 4.13	Lecturer Score for the Constructive Alignment	180
Table 4.14	Analysis Results on Pre-Test and Post-Test	182
Table 4.15	Analysis Results on the Overall GBL Framework	183
Table 4.16	Analysis Results on Sub-Component in the GBL Framework	185
Table 4.17	Pilot Test Data Analysis of Pre-Test and Post-Test for Experimental Group	188
Table 4.18	Statistical Analysis of Experimental Group Results	188
Table 4.19	Pilot Test Data Analysis of Pre-Test and Post-Test for Control Group	189
Table 4.20	Statistical Analysis of Control Group Results	189
Table 5.1	Levene Test for Homogeneity of Variance for Pre-Test.	193
Table 5.2	Student Performance Data Analysis of Pre-Test and Post-Test for Experimental Group	195
Table 5.3	Statistical Analysis of Experimental Group Results	198
Table 5.4	Student Performance Data Analysis of Pre-Test and Post-Test for Control Group	200
Table 5.5	Statistical Analysis of Experimental Group Results	203
Table 5.6	ANOVA Statistical Analysis for Student Effectiveness in Learning OOP	204
Table 5.7	Levene Test for Homogeneity of Variance for Pre-Test for Student Performance on OOP Fundamental Concept	206
Table 5.8	Student Performance on OOP Fundamental Concept (Q1 to Q10) Data Analysis of Pre-Test and Post-Test for Experimental Group	207
Table 5.9	Statistical Analysis of Experimental Group Results on OOP Fundamental Concept Understanding	211
Table 5.10	Student Performance on OOP Fundamental Concept (Q1 to Q10) Data Analysis of Pre-Test and Post-Test for Control Group	212
Table 5.11	Statistical Analysis of Control Group Results on OOP Fundamental Concept Understanding	214
Table 5.12	ANOVA Statistical Analysis for Student Effectiveness in Learning Fundamental of OOP Topics	216
Table 5.13	Levene Test for Homogeneity of Variance for Pre-Test for Student Performance on Encapsulation Topics	217

Table 5.14	Student Performance on Encapsulation Concept (Q11 to Q20) Data Analysis of Pre-Test and Post-Test for Experimental Group	218
Table 5.15	Statistical Analysis of Experimental Group Results on Encapsulation Concept Understanding	220
Table 5.16	Student Performance on Encapsulation Concept (Q11 to Q20) Data Analysis of Pre-Test and Post-Test for Control Group	221
Table 5.17	Statistical Analysis of Control Group Results on Encapsulation Concept Understanding	224
Table 5.18	ANOVA Statistical Analysis for Student Effectiveness in Learning Encapsulation Topics	226
Table 5.19	Levene Test for Homogeneity of Variance for Pre-Test for Student Performance on Inheritance Topics	227
Table 5.20	Student Performance on Inheritance Concept (Q21 to Q30) Data Analysis of Pre-Test and Post-Test for Experimental Group	228
Table 5.21	Statistical Analysis of Experimental Group Results on Inheritance Concept Understanding	231
Table 5.22	Student Performance on Inheritance Concept (Q21 to Q30) Data Analysis of Pre-Test and Post-Test for Control Group	232
Table 5.23	Statistical Analysis of Control Group Results on Inheritance Concept Understanding	235
Table 5.24	ANOVA Statistical Analysis for Student Effectiveness in Learning Inheritance Topics	236
Table 5.25	Levene Test for Homogeneity of Variance for Pre-Test for Student Performance on Polymorphism Topics	237
Table 5.26	Student Performance on Polymorphism Concept (Q31 to Q40) Data Analysis of Pre-Test and Post-Test for Experimental Group	238
Table 5.27	Statistical Analysis of Experimental Group Results on Polymorphism Concept Understanding	241
Table 5.28	Student Performance on Polymorphism Concept (Q31 to Q40) Data Analysis of Pre-Test and Post-Test for Control Group	242
Table 5.29	Statistical Analysis of Control Group Results on Polymorphism Concept Understanding	245
Table 5.30	ANOVA Statistical Analysis for Student Effectiveness in Learning Polymorphism Topics	246

Table 5.31	Levene Test for Homogeneity of Variance for Pre Test for Student Performance on Overall OOP Topics	247
Table 5.32	Student Performance on Overall Concept (Q41 to Q65) Data Analysis of Pre-Test and Post-Test for Experimental Group	248
Table 5.33	Statistical Analysis of Experimental Group Results on Overall Concept Understanding	251
Table 5.34	Student Performance on Overall Concept (Q41 to Q65) Data Analysis of Pre-Test and Post-Test for Control Group	252
Table 5.35	Statistical Analysis of Control Group Results on Overall Concept Understanding	255
Table 5.36	ANOVA Statistical Analysis for Student Effectiveness in Overall Topics.	256
Table 5.37	Scoring System Table for Usability Study	256
Table 5.38	Student Score for the Usability of GBL	257
Table 5.39	Analysis Results on Sub-Component in the GBL Framework	260
Table 5.40	Interview Feedbacks from Lecturer and Students on the Suitability of GBL Game	264
Table 5.41	Interview Feedbacks from Lecturer and Students on the Improvement of GBL Game	266
Table 5.42	Summary of Null Hypotheses Findings	267
Table 6.1	Summary of Post-Test Mean Score for Experimental and Control Groups	276
Table 6.2	Summary of Research Hypotheses Findings	277

LIST OF FIGURES

Figure 1.1.	Game Design Structure Model	25
Figure 1.2.	GBL Conceptual Framework	26
Figure 2.1.	In-Game Coding Exercises – Alice 2.0	67
Figure 2.2.	In-Game Coding Exercises – Greenfoot	68
Figure 2.3.	In-Game Coding Exercises – Darwin	69
Figure 2.4.	In-Game Coding Exercises – CodeCombat	69
Figure 2.5.	Game Design Structure Model	79
Figure 2.6.	Amory and Seagram Game Construction Framework	86
Figure 3.1.	Object-Oriented Engineering Approach	92
Figure 3.2.	Process of Constructing Proposed GBL Conceptual Framework	93
Figure 3.3.	Gameplay Phases of *Odyssey of Phoenix* development	96
Figure 3.4.	Bloom Taxonomy Application on *Odyssey of Phoenix* Development	98
Figure 4.1.	Design Model for *Odyssey of Phoenix*	134
Figure 4.2.	GBL-Driven Framework for *Odyssey of Phoenix* Development	139
Figure 4.3.	*Odyssey of Phoenix* Object Crating Process	141
Figure 4.4.	*Odyssey of Phoenix* Multi Choice Question Design	142
Figure 4.5.	Game Flow of *Odyssey of Phoenix*	145
Figure 4.6.	Overall Planet Map (a) and Area Map (b)	146
Figure 4.7.	Prison Planet (Game World 1)	148
Figure 4.8.	Old Man Home	149
Figure 4.9.	Bandit Game Map	150
Figure 4.10.	Home Planet (Game World 2)	151
Figure 4.11.	Army Recruitment Maps	152
Figure 4.12.	Final Game Settings in *Odyssey of Phoenix*	153
Figure 4.13.	In-game Class Structure in Pseudo Code and Class Hierarchy	154

Figure 4.14. Google Developer Console for the Installation in Different Android Version 174

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ARCS	Attention, Relevance, Confidence, Satisfaction
C	Content Element
E	Education Element
GAM	Game Achievement Model
GBL	Game-Based Learning
GOM	Game Object Model
HEWC	Heuristic Evaluation for Courseware
I	Interface Element
KDUUC	KDU University College
L	Lecture
MQA	Malaysian Qualification Agency
NA	Not Applicable
NPC	Non-Player Character
O	Others
OOE	Object-Oriented Engineering
OOP	Object-Oriented Programming
P	Practical
POM	Persona Outlining Model
RQ	Research Question

SGDA	Serious Game Design Assessment
T	Tutorial
TARUC	Tunku Abdul Rahman University College
TGIL	Total Guided and Independent Learning
TU	Taylor University
UI	User-Interface
UML	Unified Modelling Language
VR	Virtual Reality

APPENDIX LIST

A	Literature Summary of Existing GBL Research
B	Pre-Test Sample
C	Post-Test Sample
D	Game Validation Form For Subject Experts
E	GBL Framework Assessment Form
F	Usability Assessment Form
G	Pre-Test And Post-Test Validation Form
H	Interview Validation Form
I	Constructive Alignment Validation Form
J	Questionnaire For Pilot Testing
K	Sample Interview Questions on Application of GBL Approach in OOP Teaching and Learning
L	Sample Interview Questions on Suitability of GBL Approach in OOP Teaching and Learning
M	Feebdack Form For Lecture and Student
N	Pseudo Code
O	List of Publications

CHAPTER ONE

INTRODUCTION

1. Introduction

On these days, personal computer and mobile games have been adopted as part of the teaching and learning tools in education and training fields (Burguillo, 2010; Turner, Johnston, Kebritchi, Evans, & Heflich, 2018). Previously, these forms of game are intended mainly for children as leisure activities, but recently, this perception has changed as nowadays, adults can use games not only for entertainment but also for learning purposes. In addition, some adults even relieve their working tensions and life stresses by spending time in the virtual world of games (Colder Carras, Van Rooij, Spruijt-Metz, Kvedar, Griffiths, Carabas, & Labrique, 2018). Even so, games are often

perceived as negative influence which causes game addiction among children, youngsters and even adults. Nonetheless, some research findings indicate that by using games as teaching and learning tools, students could pick up the delivered lessons, skills and knowledge more efficiently as compared traditional teaching approach based on the same syllabus and scope (Kazimoglu, 2013).

Furthermore, the development of computer and mobile technology has catalysed the wide application of games-based teaching and learning methods in the education field (Rais, Sulaiman, & Syed-Mohamad, 2011). In this modern era, with most of the learning centres or institutes from primary to tertiary levels are equipped with computer and mobile facilities such as advanced desktop, high-speed internet access and others, it is wise to consider how to fully utilise those provided resources, especially on the use of educational games as teaching and learning tools. The availability of computer and mobile resources can thus be used to establish educational games to assist teachers and engage students in a more innovative and positive way of teaching and learning. Educational games provide interesting interaction and inspiring context for the students to learn effectively (Chang, Liang, Chou, & Lin, 2017). Through direct interaction with educational games, students can obtain useful feedback or response immediately on how they perform through a series of game stages. Thus, this can be seen that educational games currently play a crucial part in the teaching and learning process and will be of great importance in the future.

1.1. Computer programming teaching and learning using Game-Based Learning approach

Introductory of computer programming to university students with no prior knowledge remains as one of the greatest challenges in the education field (Voogt, Fisser, Good, Mishra, & Yadav, 2015). To ease both the teaching and learning process, game often seen as entertainment entity can be used for game-based learning (GBL) purposes (Tang & Hanneghan, 2010). For younger generation, playing computer games is regarded as a common culture nowadays which can be adopted in education due to its good interactivity, active participation and high engagement from students (Oblinger, 2004; Yang, 2017). Thus, GBL approach engages the players or students in actual learning undertakings using educational games as the core experience (Burguillo, 2010; Cagiltay, Ozcelik, & Ozcelik, 2015). The underlying idea of the GBL approach is to create enthusiastic involvement and accomplishment of study via the implementation of interactive game (Law, 2017; Rajaravivarma, 2005). As computer games are very common to most students, they can act as good temptation factors to attract interest and provide motivation to the students in learning object-oriented programming (OOP) concept in a more efficient way (Alaswad & Nadolny, 2015; Pivec, Dziabenko, & Schinnerl, 2003).

1.1.1. Object-Oriented Programming

Object-Oriented Programming (OOP) is the essential and introductory subject for computer science students (Anquan, Yuqing, Bailiang, Jihua, & Jie, 2010). Basically,

OOP is a complex software development paradigm which can be used to improve and develop computer applications (Klump, 2001; Schmirgel, Hietmann, Reitelshofer, Klumpp, & Kurth, 2015). Among the programming paradigms, object interaction, well-structure object and classes hierarchy system are some of the core mechanisms applied. These programming paradigms might not be easily understood by students in the initial stage. Thus, the learning and understanding of OOP paradigm can be difficult to those without prerequisite knowledge.

1.1.2. Problem statement

In Malaysia, most of the computer science undergraduates are not exposed to programming modules during their secondary or high school education (Abbasi, Kazi, & Khowaja, 2017; Rais, Sulaiman, & Syed-Mohamad, 2011). Therefore, this unavoidably creates great obstacles in the subsequent teaching and learning process of OOP at university or tertiary level. As of 2019, some of the major issues faced by programming lecturers during the teaching process include the following (Abbasi, Kazi, & Khowaja, 2017; Deneyimleri & ve Engeller, 2010; Ozmen & Altun, 2014; Rais, Sulaiman, & Syed-Mohamad, 2011; Sheard, Carbone, Chinn, & Laakso, 2013; Tan, Ting, & Ling, 2009):

- Inadequacy of exposure and actual experience in programming
- Short course time for programming teaching and learning
- Variation of understanding level among student leading to difficulty of lecture delivery

From students' perspective, the following issues encountered can delay their learning curve as well as can create great hurdles in their development (Abbasi, Kazi, & Khowaja, 2017; Ozmen & Altun, 2014; Rais, Sulaiman, & Syed-Mohamad, 2011; Tan, Ting, & Ling, 2009):

- Limited understanding of programming concept in the beginning of the course
- Programming language as the single context can be mundane and cause disinterest among students
- Low performance on learning programming

Targeting the issues above, educational games are suitable for overcoming the challenges faced by programming lecturers as well as by students (Abbasi, Kazi, & Khowaja, 2017; Ibrahim, Yusoff, Omar, & Jaafar, 2010; Rais, Sulaiman, & Syed-Mohamad, 2011). This is because by applying the GBL approach, the learning environment has been converted from lecture-centered to interactive-centered method, whereby students can easily visualize the objects in OOP (Law, 2017; Rajaravivarma, 2005). Therefore, GBL approach not only provides real-time interaction, it also creates interest and learning motivation among students. Eventually, students will be able to learn OOP more effectively during their course of study. In addition, through this approach, students can decide their preferential pace in learning by creating their own schedule. As different levels of understanding are common among students, they can control the learning process in term of stage or pace by deciding whether to stay at one game level or to proceed further.

To date, some educational games for learning programming are built based on serious game model, which mainly focus on the learning process followed by the assessment of performance. Thus, the learners are expected to participate in numerous tests and quizzes as well as programming coding exercises in order to continue the game progress. Some of the available educational games include code combat (Vahldick, Mendes, & Marcelino, 2014), Alice 2.0 (Mullins, Whitfield, & Conlon, 2009; Weintrop & Wilensky, 2016), Greenfoot (Kölling, 2015; Kölling, 2010) and Darwin (Edgar, 1987; Rais, Sulaiman, & Syed-Mohamad, 2011).

As mentioned, one of the major challenges faced by student in the learning process is mainly lack of understanding on programming paradigm especially on OOP paradigm (Mathrani, Christian, & Ponder-Sutton, 2016). Thus, in order to eradicate such issue, it is proposed to develop an educational game in accordance with GBL approach that emphasizes on playing and learning at the same time whereby this could be a feasible solution.

In this research work, a serious game model is needed to develop a suitable educational games for the teaching and learning of OOP based on gamification concept (Rodríguez Corral, Civit Balcells, Morgado Estévez, Jiménez Moreno, & Ferreiro Ramos, 2014). Serious game model focuses on learning element with game element being applied as supplementary support to develop the proposed and unique conceptual framework for this research. According to this model, in the beginning stage, game introduction should gain the attention of the learner and play the role to inform the player regarding the gameplay (Tang & Hanneghan, 2010). Following that, game tutorials are also provided to help the players to familiarize themselves with the

gameplay process (Tang & Hanneghan, 2010). In the game tutorial stage, it is necessary to present stimulating materials to the players and useful guidance to aid them in starting the game. The gameplay environment also incorporates the following components such as abstract conceptualization, reflective observation, active experimentation and authentic experience to form game cycles that involves synthesis of learning process, elicit performance and feedback (Tang & Hanneghan, 2010; Tang & Hanneghan, 2014).

1.1.3. Research gap

Review of literature suggests that a number of studies have been carried out to study the use of GBL for learning computational thinking, logical thinking and programming concepts. (Mathrani et al., 2016; Chandrashekar et al., 2018; Bittencourt, et al., 2015; Davis 2017; Florea et al., 2016; Hayat 2016; Hou 2015; Tabet et al., 2016; Topalli & Cagiltay 2018; Utting 2010). Moreover, most of these studies have been mainly undertaken to understand the learner or student performance towards learning programming. As evident from the studies, there has been a rapid improvement of student's performance in learning programing related subject or module due to the high demand of computing talent from industry (Hayat 2016; Hou 2015; Tabet et al., 2016; Topalli & Cagiltay 2018; Utting 2010). With a change in student performance and perceptions regarding the GBL role of and the consequent of using GBL for learning purposes, there arises a need to study and analyse the efficiency of GBL in learning programming specifically for OOP (Moreno-León & Robles 2016; Lameras et al., 2016;Khenissi et al., 2015; Ke 2016; Azmi et al ., 2015; Huizenga et al., 2017;

Marchetti & Valente 2015; Connolly et al., 2012; Barik et al., 2016; Arnab et al., 2015; Battistella & Wangenheim 2016; Sáez-López et al., 2016). There is also a need for a better understanding of the efficiency factors, which have brought about a paradigm shift in the learning programming in existing approach leading to new learning trends throughout the world.

The scopes of most of the existing studies are either including the game with programming coding exercises and formative assessment in single context (in particular programming language) or learning programming by creating game. Besides that, most of the proposed GBL frameworks are focusing on the learning by creating game. Moreover, there are no or very few studies, which only through playing computer game in order to achieve the learning objective. As mention in the Section 1.1.2, the major problems for student learning programming concept, specifically in OOP concept is lack of understanding and not able to apply the concept appropriately. Although some of the study mentioned, had proposed to solve this problems by creating game with some programing exercise. However, there is lack of research that focusing on learning by playing game specifically in OOP concepts. This study aims to fill the existing research gap. This study begins with analyzing the possibility of applying GBL in learning OOP programming concepts by focusing on playing GBL game. Understanding the learners or student preference and identifying the factors that affect the efficiency of the framework can help in terms of the student learning performances towards OOP paradigm. The study also has implications for producing a GBL driven framework to the universities with the aims of designing GBL games that should be used to learn OOP paradigm effectively and stimulate student performance.

1.2. Significance of study

Existing teaching and learning methods are found to be insufficient to support the undergraduates who are usually novices or beginners (First-year degree students) in programming knowledge (Abbasi, Kazi, & Khowaja, 2017; Rais, Sulaiman, & Syed-Mohamad, 2011; Tan, Ting, & Ling, 2009). Thus, GBL approach can be applied as an efficient method for them to learn OOP and improve their understanding as well as performances in study. Currently, there are lacking of effective and efficient computer and mobile games which serve as teaching and learning OOP tool as proven empirically by various studies (Kazimoglu, 2013). Thus, this research work proposes an educational game, also known as *Odyssey of Phoenix,* in both desktop computer and mobile versions as created based on GBL design approach model specifically for the teaching and learning of OOP paradigm. *Odyssey of Phoenix* is designed to ensure the learning process is simple, motivating and attractive. To form the game challenge based on progressive understanding of OOP, the gameplay divides the learning content into several levels or quests. Thus, the players or students are required solve each quest which adopts different gameplay mechanics to suit the learning objective of OOP. In order to complete each quest, players or students are required to communicate with non-player characters, to solve riddles and to complete given tasks which all serve the learning OOP purpose. When the players fully understand and apply the OOP knowledge in the gameplay, they will progress from quest to quest until completing the learning of the paradigm.

In contrast with other educational games for learning programming such as Alice 2.0, Greenfoot, Darwin and CodeCombat, the *Odyssey of Phoenix* only focuses

on the gameplay by carrying out the learning objective without the prerequisite of coding and programming skills. These GBL programming are developed with the extensive coding game mechanics.

All of these games have their own approaches and objectives; however they are not designed specifically to accommodate the learning of OOP. Thus, applying these educational games for teaching and learning might not be sufficiently effective and efficient for novices to learn OOP. In this case, *Odyssey of Phoenix* is developed mainly to teach OOP as well as to focus on one of the most efficient ways to learn, by playing games. This game can act as an engaging learning medium for OOP beginners. Furthermore, with the availability of step-by-step guidance, it is also suitable for both moderate and advance learners to achieve the learning objectives based on their personal preferences and obtained skilled from the game. Currently, there has not been a computer and mobile game established mainly for teaching and learning of OOP, whereby *Odyssey of Phoenix* would be regarded as one of the first educational games that feature a gameplay without coding practice.

1.3. Research background

The existing way of teaching programming is not appealing to undergraduates as these conventional lectures and tutorial classes are not adequately interesting and provides only single-way learning environment (Gardner, 2017; Shri, Wai, Peter, Shri, & Peter, 2006). Nowadays, most students prefer to their own self-learning with ample of freedom. Therefore, the new teaching and learning pedagogy in most universities are

emphasizing student-centred learning approach to cater the changing environment. Computer and mobile games are considered to be the suitable tools in modern era to execute the student-centred teaching and learning system.

As mentioned, OOP paradigm is regarded as a critical fundamental knowledge in the IT industry and education field; at the same time, it is also known to be as one of the most difficult programming studies to be taught by lecturers and learnt by students, respectively. In the initial stage of tertiary education, even computer science stream students are mostly unable to capture and visualize the concept of the OOP paradigm completely. This necessitates the use of computer and mobile game as the teaching and learning tool to simplify the learning OOP for the students as well as provides an efficient and fun OOP design learning environment for them.

1.3.1. Challenges of learning OOP for computer science undergraduates

Various difficulties met by undergraduates with learning OOP are generally associated with lack of prerequisite knowledge, meaningful engagement with the lectures delivered and also low enthusiasm especially in learning the theoretical side of OOP (Beaubouef & Mason, 2005; Kinnunen & Malmi, 2006; Wong, Hayati, & Tan, 2016a).

In addition, the exercises, tasks, assignments and even homework distributed for the learning OOP also contributes to some of the undergraduates' dislike as these are considered to be demanding and tiresome (Bennedsen & Caspersen, 2008; Bennedsen, Caspersen, & Kölling, 2008; Gardner, 2017). Undergraduates show great

issues when designing a program to solve assigned work, applying functionality into procedures, learning language syntax, identifying bugs in program and grasping basic programming concepts. Especially when undergraduates are required to think innovatively on practicing new syntax and grammar to communicate, they are not conscious about the significant analysis and design with majority of them start coding immediately after undertake a programming assignment or project (Dalal, Dalal, Kak, Antonenko, & Stansberry, 2009; Law, 2017; Rajaravivarma, 2005; Watson & Li, 2014). Given the issues encountered by the students, this implies that the current method of teaching programming is inadequate. Nonetheless, despite such observation, most undergraduates still agree that learning by example, exercises, and interactive visualizations are the most appropriate materials for learning programming.

According to Moser (1997), programming is a multi-layer skill which can be boring, intimidating, and unrelated to a student's day-to-day experience where they only learn in a single context. Most undergraduate students in Malaysia do not have any programming experience before they enrol into a degree programme. Most of them are learning programming in a single context, meaning only one programming language. This situation causes the student to have negative programming habits, which affect their adaptability to learn other programming languages. Subsequently, most students begin to think that programming is difficult to learn and apply. Eventually, they will refuse to learn programming.

Furthermore, with poor teaching methods and tools, undergraduates shows very low level of interaction as they prefer to have smooth and swift learning process on relevant computational artifacts (DiSalvo, Guzdial, Bruckman, & McKlin, 2014;

Guzdial & Adams, 2014). With such issues, this can lead to higher dropout rate for learning OOP modules as the undergraduates might felt disconnected from the teaching and learning process (Beaubouef & Mason, 2005; Kinnunen, 2009; Sharmin, 2018). In some cases, learning programming difficulty can cause high failure rate in computer science courses (Bennedsen & Caspersen, 2007; Watson & Li, 2014). Even students who have pass programming courses, they are still not able to program or use programming code to solve problems (Loftus, Thomas, & Zander, 2011; Thomas, Zander, Loftus, & Eckerdal, 2017). A study about learning difficulties in programming courses for undergraduate students was conducted in Malaysia, involving 185 undergraduate respondents with most respondents were low in confidence when it came to their programming skills (Hsu & Mimura, 2017; Tan, Ting, & Ling, 2009).

1.3.2. Factors influencing students' learning in OOP

Students' cognitive engagement on the learning of programming modules can be influenced by different factors. Student-based factors, teaching-based factors and education system are proposed by Biggs (1987) while Helme and Clarke (2001b) suggests that the individual, the environment and the learning task are key factors influencing the OOP teaching and learning process.

In order for students to be successful learners, they need to show motivation, will, skill and capability (Abbasi, Kazi, & Khowaja, 2017; Helme & Clarke, 2001a, 2001b). Of course, teachers or lecturers are also the key factors that ensure students are motivated to learn and to think on how to develop better programming skill and

understanding of OOP paradigm. On an overall perspective, students can learn well if these traits are well-catered which include knowledge, skills, dispositions, needs, values, goals, perception, expectations and aspirations (Abbasi, Kazi, & Khowaja, 2017; Helme & Clarke, 2001a, 2001b). Else, most students are unaware of their understanding level on their introductory courses, especially first year tertiary student (McCracken, Almstrum, Diaz, Guzdial, Hagan, Kolikant, Laxer, Thomas, Utting, & Wilusz, 2001; Murphy, Crick, & Davenport, 2016).

Prior academic experiences, students who have strong science and mathematics backgrounds exhibit better learning ability on programming in their first year of course (Akar & Altun, 2017; Bergin & Reilly, 2005a, 2005b; Byrne & Lyons, 2001). This can be related with their style of learning as well as their stronger problem solving ability (Beaubouef, Lucas, & Howatt, 2001; Bouvier, Lovellette, Matta, Alshaigy, Becker, Craig, Jackova, McCartney, Sanders, & Zarb, 2016; Goold & Rimmer, 2000). Thus, self-perception and specific cognitive ability obtained during the early stage of education are also crucial for students to have stronger foundation in tertiary education (Bergin & Reilly, 2005a, 2005b; Quille, Bergin, & Mooney, 2015).

1.3.3. Computer and mobile use as teaching and learning tool

Computer and mobile games involves interactivity and communications and requires the players to join the gameplay. Therefore, they are highly suitable to be tailored as teaching and learning tool; however, several game specifications are needed to be designed effectively such as the game interfaces, storyboard and the rules of the games.

Retaining the players' interest and focus on the gameplay is highly depending on the user interface. A user-friendly, simple to navigate and beautiful game interface will leave the learners experience more excitement and less frustration during the gameplay. At instance, the interface of game represents the very first impression for the learner to play and learn from the game. Thus, a good interface eventually creates a better user experience enabling more comfortable learning of OOP. Games tutorials are often provided as a guide so that the gamers or students or learners can explore the gameplay themselves in more details. Thus, game designers should consider not to provide an overly comprehensive tutorial for the learner in order to avoid the high dependency on the guideline. For example, *Banjo Kazooie,* is a game which requires the player to demonstrate the ability to complete certain tasks at level one before proceeding to the next level. In case, the players are stuck at one level for too long, there will be tutors available for assistance (Pagulayan, Keeker, Wixon, Romero, & Fuller, 2003; Wardaszko, 2016).

Computer and mobile games should have clear objectives with different level of difficulties as these aspects can produce educationally effective teaching and learning tools (Gentile & Gentile, 2008; Kim & Lee, 2015). The pace of learning is adjustable according to the level of the learner, which can be beneficial to effective learning. By designing the learning approach to be active in a practice-feedback-practice method where once a skill or knowledge is acquired, the same skill is practiced to a point of complete mastery both extrinsically and intrinsically. As computer and mobile games can be adaptable to different skill levels, different level of players can adopt including novice player. If the gameplay provides the knowledge or skills to be learnt in one

context, it is likely that the mastered skills are retainable as in the gameplay, these skills are practiced in multiple ways.

The first and second aspects are related to the difficulty and speed of the game. Most of the commercial games have the difficulty options for learners to choose, usually simple, average and hard levels. Different levels of difficulty can be incorporated with different speeds at each level. Therefore, learners can choose the level based on their skills and capabilities, respectively. Meanwhile, learners also can practice on the easy level to improve their skill. Actually, educational computer game can adopt this approach to retain the level difficulty that matches the learner's competency level. According to Csikszentmihalyi and Csikszentmihalyi (1975), their work claimed that this chain or ramping of the difficulty could form a circle called flow-state, which can be explained in flow-type engagement. If ones finds minor attention for self-monitoring instead of fully occupied on completely on the task, such practice often energized ones due to the high level of stimulation which has arisen from the challenge of task completing and feedback. Most of the current educational games are using this technique to guide learners how to play the game based on game tutorial or demonstration. Therefore, educational computer game could adopt this aspect when developing the game.

Overlearning issues should be considered in the game design as some of the current games do not show concern on this matter. The consequence can be adverse causing the learners to abandon the game because they might feel forced to repeat the same skills in the entire game. Eventually, learners might experience both boredom and frustration when playing this kind of game. Especially in educational game

development, this issue should be clarified and avoided before developing the game. Overlearning issues blocks the learners' interest in the entire learning process. The use of computer and mobile games in education must be calibrated to ensure that the learners are able to learn the skill they are supposed to learn from each level. To gauge that, the feedback from the game plays a crucial part. Thus, educational computer and mobile game should include feedback function as the learners can immediately obtain results or feedback on their progress in the learning process. Thereby, they will be able to know their learning curve and the understanding level of the taught topics. Multiple problem solving circumstances are very useful to let the learners in practicing their skill and knowledge with flexibility. Therefore, such aspect can help to prepare them in applying the learnt skills even in different circumstances. Table 1.1 summarises some of the GBL research from 1992 to 2011. As can be observed, most of the results indicate that GBL showed positive outcome which supports better learning outcome. Some students also showed higher favourability if the lessons or lectures were presented using GBL approach.

Table 1.1

Analysis of Existing GBL Research

Research Work	Sample Size	Key Findings
Randel, J. M., Morris, B. A., Wetzel, C. D., & Whitehill, B. V. (1992). The effectiveness of games for educational purposes: A review of recent research. *Simulation & gaming*, *23*(3), 261-276.	67	Based on the outcome, 56% showed no different between games and conventional instruction. About 32% favoured games while 5% favoured conventional instruction (Randel, Morris, Wetzel, & Whitehill, 1992).
Wolfe, J. (1997). The effectiveness of business games in strategic management course work. *Simulation & Gaming*, *28*(4), 360-376.	7	GBL significantly improved knowledge level over the conventional methods (Wolfe, 1997).
Hays, R. T. (2005). *The effectiveness of instructional games: A literature review and discussion* (No. NAWCTSD-TR-2005-004). Naval Air Warfare Center Training Systems Div Orlando Fl.	105	An instructional game must be designed to meet specific objectives for effective learning. GBL should be embedded with feedback and debriefing features (Hays, 2005). Instructional support should be provided to help learners understand how to use the game for better learning experience.
Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research*, *34*(3), 229-243.	32	Higher cognitive gains were observed in GBL methods versus traditional techniques. Students showed improved attitudes toward GBL (Vogel, Vogel, Cannon-Bowers, Bowers, Muse, & Wright, 2006).
Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. *Handbook of research on effective electronic gaming in education*, *1*, 1-32.	65	GBL outcomes were mainly positive (represented about 52% of the test results) (Ke, 2011).
Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel psychology*, *64*(2), 489-528.	65	Overall 20 % increase in the confidence level with GBL approach – 9 % better for retention; 14 % better for procedural knowledge and 11 % better for declarative knowledge (Sitzmann, 2011)

1.4. Research aim and objectives

This research work aimed to develop a GBL driven framework specifically for OOP teaching and learning. A computer and mobile educational game, named as *Odyssey of Phoenix*, was designed and developed specifically for the teaching and learning OOP concepts including fundamental of OOP, Abstraction, Encapsulation, Inheritance, and Polymorphism in Malaysia at tertiary level education to improve student learning performance. Addressing the research aim, specific objectives of this research with their scope of work were described as follows:

a) To develop a GBL driven framework specifically for OOP teaching and learning purposes

b) To create a new computer/ mobile game suitable for students to learn OOP at tertiary level;

c) To investigate whether the GBL driven framework developed can be an educationally efficient framework to support the teaching and learning of OOP in different contents (fundamentals of OOP, Abstraction, Encapsulation, Inheritance, Polymorphism);

d) To perform comprehensive statistical study and evaluate the data collected from the rigorous assessment evaluations.

1.5. Research questions

Based on the aim of this research, the main research question raised from this study was as follows:

"Can computer and mobile game that designed based on GBL driven framework improve the learning OOP efficiently among beginners?"

In addition to the main research questions, this study also seeks to discourse the following more specific research questions:

a) Is there a significant difference of students' mean score for pre-test and post-test between control group students learning through GBL approach and students learning through traditional teaching approach?

b) Is there a significant difference of students' performance in learning fundamental concept in OOP between students learning through GBL approach and students learning through traditional teaching approach?

c) Is there a significant difference of students' performance in learning Encapsulation in OOP between students learning through GBL approach and students learning through traditional teaching approach?

d) Is there a significant differences of students' performance in learning Inheritance in OOP between students learning through GBL approach and students learning through traditional teaching approach?

e) Is there a significant difference of students' performance in learning Polymorphism in OOP between students learning through GBL approach and students learning through traditional teaching approach?

f) Is there a significant difference of students' performance in learning overall OOP concept between students learning through GBL approach and students learning through traditional teaching approach?

1.6. Research hypotheses

With six research questions presented above, six research hypotheses are generated for statistical analysis in every quasi-experimental study:

- H_{a1}: There is significant difference of students' mean score for pre-test and post-test between control group students learning through GBL approach and students learning through existing teaching approach.

- H_{a2}: There is significant difference of students' performance in learning fundamentals in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{a3}: There is significant difference of students' performance in learning Encapsulation in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{a4}: There is significant difference of students' performance in learning Inheritance in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{a5}: There is significant difference of students' performance in learning Polymorphism in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{a6}: There is significant difference of students' performance in learning overall concept OOP between students learning through GBL approach and students learning through existing teaching approach.

Besides that, six null hypotheses are also generated for statistical analysis in every quasi-experimental study:

- H_{o1}: There is no significant difference of students' mean score for pre-test and post-test between control group students learning through GBL approach and students learning through existing teaching approach.

- H_{o2}: There is no significant difference of students' performance in learning fundamentals in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{o3}: There is no significant difference of students' performance in learning Encapsulation in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{o4}: There is no significant difference of students' performance in learning Inheritance in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{o5}: There is no significant difference of students' performance in learning Polymorphism in OOP between students learning through GBL approach and students learning through existing teaching approach.

- H_{o6}: There is no significant difference of students' performance in learning overall concept in OOP between students learning through GBL approach and students learning through existing teaching approach.

1.7. Conceptual framework of research

To expand the wider application of *Odyssey of Phoenix* in both computer and mobile games for teaching and learning OOP in tertiary education, the Game Design Structure

Model by Tang and Hanneghan (2010) (Figure 1.1) is applied and referred. In this model, several quintessential theories are included in the serious game model such as ARCS Theory of Motivation (Keller, 2009; Li & Keller, 2018), Constructive Theory, Conditions of Learning Theory, Operant Conditioning Theory (Ebrahimzadeh & Sepideh, 2017; Wu, Chiou, Kao, Hu, & Huang, 2012), Bloom Taxonomy (Arnab, Lim, Carvalho, Bellotti, De Freitas, Louchart, Suttie, Berta, & De Gloria, 2015) and Hierarchy of Needs Theory (Jung, Kaß, Schramm, & Zapf, 2017; Partala & Kallinen, 2011). By utilizing these learning theories, more efficient and coherent serious game framework for games developer and games lecturer can be established. These learning theories also form the pillar of the framework required (Figure 1.2) to ensure the education game is more fun-oriented instead of emphasizing purely on coding exercise. Furthermore, this is to fulfil one of the main objectives of this research which involves the generation of high interest and motivation among student as well as the elimination of the learning barriers faced by them. For this research, the conceptual framework was referred for the *Odyssey of Phoenix* development can be divided to four layers namely main layer (core layer), gameplay (inner layer), learning theory (middle layer) and presentation (outer layer), which will be detailed in Chapter Four. Each layer plays significant role in ensuring *Odyssey of Phoenix* is attractive, practical and feasible in OOP teaching and learning process.

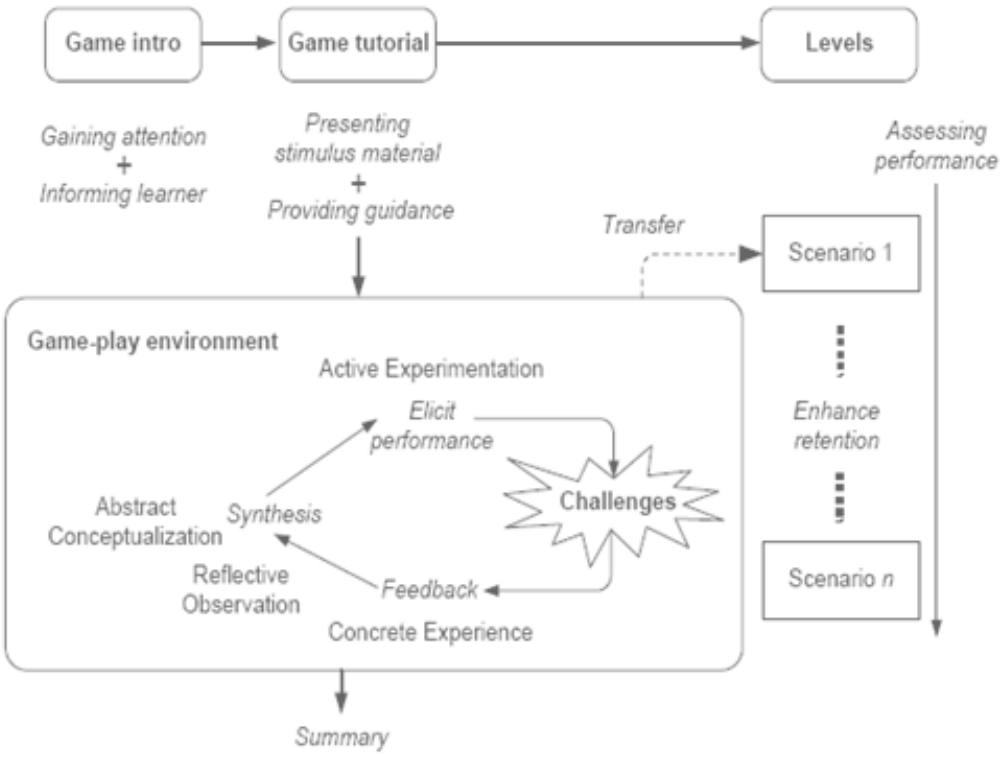

Figure 1.1. Game Design Structure Model

This study adapted the Game Design Structure Model (Tang and Hanneghan, 2014). The purpose of the model is to provide well-designed structure to develop a computer game that aiming for the presentation of learning material in a guided and elaborative manner that closely integrated with meaningful activities introduced as a form of play. The model was modified to four layers to fit the proposed game-based learning conceptual framework. The four layers are Main Layer, Gameplay Layer, Learning Theory Layer and Presentation Layer. The main game-play environment (such as elite performance, challenges, feedback and synthesis) from the model was identical with the Gameplay layer in the proposed game-based learning conceptual framework. Others elements are analyzed accordingly to consider in the proposed game-based learning conceptual framework in respective layers. Thus, the game

introduction, game scenario and level elements' requirements from the model are considered in presentation layer. The presentation layer focuses on designing a simple and attractive gaming experience to the students in order to retain students' learning motivation and attention. While the remaining elements' requirements (such as active experimentation, concrete experience, reflective observation, abstract conceptualization) from the model are consider in Learning Theory Layer that covered relevant theories such as constructive theory, mastery learning, condition of learn, operant conditioning theory, hierarchy of Need and ARCS theory of motivation are included. Additionally, the Main Layer had been added to this model, which signifies the variables of required for research, with five main sub-components such as student, lecturer, learning content, learning difficulties and learning outcome.

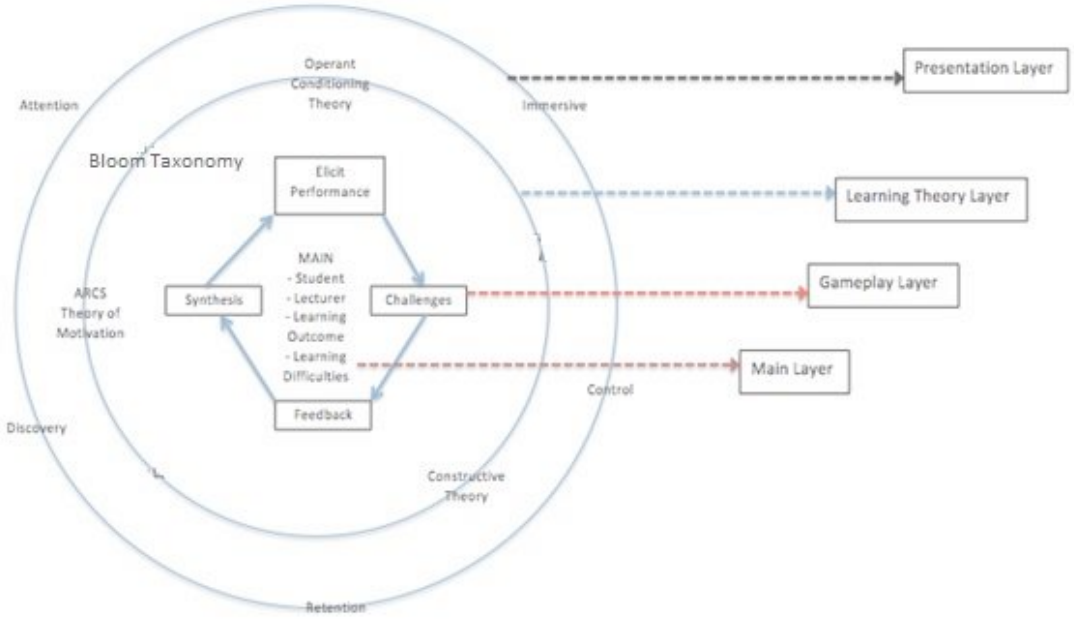

Figure 1.2. GBL Conceptual Framework.

Each layer is inter-related because the proposed GBL game is designed to be a real time application. Main layer of the model signifies the variables of required for research, with five main sub-components such as student, lecturer, learning content, learning difficulties and learning outcome. Gameplay layer includes the concepts of student-centred learning, so that the learners can take the full ownership on the learning time and schedule. This layer presents relevant sub-components such as elicit performance, challenges, feedback and synthesis. For the learning theory layer, relevant theories such as constructive theory, mastery learning, condition of learn, operant conditioning theory, hierarchy of Need and ARCS theory of motivation are applied in the GBL game model to create appropriateness in the learning tool. To ensure the user interface design requirement is met, the presentation layer focuses on designing a simple and attractive gaming experience to the students in order to retain students' learning motivation and attention. These sub-components such as immersive, attention, control, discovery and retention are core elements in fun gameplay design.

1.8. Scope and limitation of study

The identified scopes and limitations from literature review formed the basis of this research. Below shows the core scope of work as well as the limitation or boundary:

- *Odyssey of Phoenix* testing only aimed for first year computer science programme students
- Fundamental of OOP topics would be included in the gameplay and covered
- The study group was targeted only at higher learning institutions in Malaysia
- Only considered learning environment

- Both required hardware and software were acquired depending on the facilities conditions of the higher learning institutions

Computer and mobile games can be categorized as real person game, sport game, simulation game, adventure game and others (Pallavicini, Ferrari, & Mantovani, 2018). However, not all game genres are suitable to be developed as teaching and learning tools as some are more suitable for entertainment purpose instead of learning purpose. For instance, PACMAN, as one of the famous games in the world, only requires player to control the character's motion and to collect all the required items in order to proceed to the next level whereby the gameplay actually does not serve any learning mode (Pallavicini, Ferrari, & Mantovani, 2018). To develop a robust computer and mobile educational game, the selection of subject or module is extremely important because certain subjects require practical session and workshop such as programming subject. This would limit the game genres which can be applied in the game development. In this study, theoretical subject such as OOP being more flexible for game development was selected. This research applied a hybrid game genre which involved both role-playing game (RPG) and puzzle-solving mechanism as the design for *Odyssey of Phoenix* due to their high suitability for the development of teaching and learning tool. In the game development, *Odyssey of Phoenix* also only takes into account of fundamental of OOP, which included Abstraction, Encapsulation, Inheritance and Polymorphism being the more important learning elements to simplify the learning process.

Sampling of the *Odyssey of Phoenix* data was proven to be challenging due to different institutions having different learning environment. Nonetheless, to reduce the

data complexity and improve accuracy, the data collection would focus mainly on learning environment and be analysed with statistical methods. As mention above, different learning environments could result in the different types of hardware and software requirement. Therefore, when developing *Odyssey of Phoenix* as learning tool, a more general platform (hardware and software) was included into the design for wider application.

From this thesis work, the research scope not only seeks to fill the research for this interesting topic, but also to identify and evaluate how *Odyssey of Phoenix* can actually be applied as teaching and learning tools for teaching OOP in Malaysia's higher learning institutions.

1.9. Operational definition

In this doctoral study, six main terms are identified as the key concepts for OOP teaching and learning game development. They are specifically defined for the context of this research as below.

1.9.1. Object-oriented programming

Classing an extensible template for creating objects, providing initial values for attribute and implementing function and object refer to a particular instances of a class where the object can be a combination of variables and functions (Schmirgel, Hietmann,

Reitelshofer, Klumpp, & Kurth, 2015). OOP is referred as one of the programming paradigms that focuses on the concept of object or instance, which its structures contains both attributes and operational methods (Klump, 2001).

1.9.2. Game-Based Learning approach

Game is referring to a structured playing with game rules, usually undertaken for enjoyment and learning purposes (Kapp, 2012; Weston & Barney, 2016). The key components of games are goals, rules, challenges and interaction (Kapp, 2012; Weston & Barney, 2016) whereas learning is the act of acquiring new, modifying knowledge and skills and may involve synthesizing different types of information (Tang & Hanneghan, 2010). By combining game and learning, several theorists have applied play as the first form of learning (Burguillo, 2010). Students will experiment with the knowledge, learn the rules, and interact through play.

GBL is a type of game play that has defined learning outcomes (Kazimoglu, 2013). Generally, GBL is designed to balance subject matter with gameplay and the ability of the player to retain and apply said subject matter to the real world. GBL approach is also referred as the method or framework for games developer or programming lecturers to develop game as programming learning tool (Kazimoglu, 2013) .

1.9.3. Serious game model

Serious games are simulations of real-world events or processes designed for the purpose of solving a problem (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Soflano, Connolly, & Hainey, 2015). Although serious games can be entertaining, their main purpose is to train or educate player. Serious games sometimes deliberately sacrifice fun and entertainment in order to achieve a desired progress by the player. Serious games are not just a form of game genres but a category of games with different purposes and primarily focus on an audience outside of primary or secondary education (Kazimoglu, Kiernan, Bacon, Mackinnon, 2012).

1.9.4. Programming lecturers and students at tertiary level

Programming lecturers refer to the academicians who teach programming subject at undergraduate level in Malaysia public and private universities. For this study, programming students are referred to the undergraduate degree year one students who enrol into computer science related programs.

1.9.5. Game developers

In this research, game developers are usually the game programmer or game designer who focus on creating the gameplay with GBL approach.

1.9.6. Key topics of learning OOP

The key topics of learning OOP for this research are Abstraction, Encapsulation, Inheritance, and Polymorphism. The purpose of Abstraction is to hide the relevant data about an object in order to reduce complexity and increase efficiency. Encapsulation is a process in OOP for packing data and functions into a single component to make the object can react accordingly. Inheritance in OOP mainly applies when an object or class is based on another object or class, using the same implementation specifying implementation to maintain the same functions. Lastly, Polymorphism is the provision of a single interface to entities of different types of values.

1.10. Thesis outline

This doctoral thesis consists of five chapters, focusing on the development of a learning OOP tool, with each chapter describes the sequential progress of the research work as follows:

Chapter One provides a brief introduction to the problems faced by lecturers and students in the teaching and learning of OOP as well as proposes the use of computer and mobile game constructed based on the GBL driven framework as an effective solution to this issue. Based on the current literature, many studies evidence and verify that the empirical investigation on the proposed computer game as an efficient tool for learning OOP is absent. Due to this reason, the current work forms the major research

question and the research objectives and also the methodology to address the research gap identified.

Chapter Two includes a thorough and systematic literature review on the current available educational games on teaching and learning of computer-related courses. Further study was performed to investigate the core factor influencing the students' learning progress. In this chapter, the learning theories as mentioned in Chapter One were more comprehensively discussed in terms of their fundamentals.

Chapter Three provides the research methodology adopted in Pre-Test and Post-Test for the Odyssey of Phoenix. The research model, in the form of quasi-experiment, was detailed with respect with Abstraction, Encapsulation, Inheritance and Polymorphism. The result validation was also performed with the use of analysis of variance (ANCOVA) and analysis of covariance (ANCOVA).

Chapter Four describes the design, development as well as the validation of *Odyssey of Phoenix* with theoretical supports. In addition, the storyline, dialogue between characters and progress of game was also critically designed and presented in this chapter. To construct *Odyssey of Phoenix*, the game pseudo code was generated.

Chapter Five discusses all the main findings generated from this research work based on the evaluation of subject experts, students' performances and statistical supports. The tabulated feedback was also presented in this chapter as a reference for future development.

Chapter Six concludes and summarises the main results of the research. It also provides recommendation for future work in order to improve of GBL for OOP learning.