DEVELOPMENT OF COPS BOARD GAME ON LEARNING ORGANIC CHEMISTRY SYNTHETIC PATHWAYS AMONG MATRICULATION STUDENTS

RAJAKUMAR A/L RAMACHANDRAN

UNIVERSITI PENDIDIKAN SULTAN IDRIS

2022

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ABSTRACT

This study aims to develop Synthetic Pathways of Organic Compounds (COPS) and investigate matriculation students' perceptions towards the board game. The research employed the developmental design based on ADDIE model. A total of 171 respondents participated in this study where data were gathered via four types of questionnaire. The needs analysis survey on 36 chemistry educators revealed 86.1% of them required or had intention to use GBL in their organic chemistry lessons and 91.7% agreed on suitability of GBL for the same purpose. After designing and developing COPS, a questionnaire was administered among five experts whom averagely scored 90.8% of agreement on its validity. Pilot study on 30 respondents showed high reliability coefficient ($\alpha = 0.993$). One hundred and five matriculation students strongly agreed that COPS has positive impact on learning organic synthetic pathways with high mean scores for all the five constructs. Findings showed mean scores and standard deviations for goals, board design, board organisation, playability, and usability were M=4.46; SD=0.707, M=4.42; SD=0.745, M=4.31; SD=0.811, M=4.46; SD=0.747, and M=4.37; SD=0.770 respectively. In conclusion, COPS was perceived as a useful learning tool for organic synthetic pathways. The study implies COPS would be able to offer more fun and joyful learning environment in teaching and learning of the topic.

PEMBANGUNAN PERMAINAN PAPAN COPS BAGI PEMBELAJARAN LALUAN TINDAK BALAS SINTETIK KIMIA ORGANIK DALAM KALANGAN PELAJAR MATRIKULASI

ABSTRAK

Kajian ini bertujuan membangunkan *Synthetic Pathways of Organic Compounds* (COPS) dan mengkaji persepsi pelajar matrikulasi terhadap permainan papan COPS. Kajian ini menggunakan reka bentuk pembangunan berdasarkan model ADDIE. Sejumlah 171 responden terlibat dalam kajian ini yang merangkumi penggunaan empat jenis soal selidik. Pada fasa analisis, satu kajian analisis keperluan dilaksanakan terhadap 36 orang guru kimia di mana 86.1% daripada responden memerlukan atau mempunyai niat untuk menggunakan kaedah pembelajaran berasaskan permainan dalam pembelajaran kimia organik manakala 91.7% responden bersetuju mengenai kesesuaian kaedah ini bagi tujuan yang sama. Selepas mereka bentuk dan membangunkan COPS, satu soal selidik ditadbirkan dalam kalangan lima orang pakar di mana tahap persetujuan secara puratanya menunjukkan nilai kesahan yang tinggi iaitu 90.8%. Kajian rintis terhadap 30 responden pula menunjukkan nilai kebolepercayaan yang tinggi (α = 0.993). Seramai seratus lima orang pelajar matrikulasi sangat bersetuju bahawa COPS memberikan impak yang positif dalam pembelajaran laluan sintetik organik dengan nilai skor min yang tinggi direkodkan pada kesemua lima konstruk. Dapatan kajian menunjukkan nilai skor min dan sisihan piawai bagi objektif, reka bentuk papan, susunatur papan, kebolehmainan, dan kebolehgunaan masing-masing direkodkan sebanyak M=4.46; SD=0.707, M=4.42; SD=0.745, M=4.31; SD=0.811, M=4.46; SD=0.747, and M=4.37; SD=0.770. Kesimpulannya, min dan peratus persetujuan responden yang tinggi membuktikan bahawa permainan papan COPS diterima baik sebagai alat bantu belajar. Implikasinya, penggunaan permainan ini memberikan peluang kepada pelajar merancang serta menulis laluan tindak balas sintetik kimia organik dengan betul dalam suasana pembelajaran yang lebih menarik dan ceria.

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LIST OF ABBREVIATIONS

BGG	Board Game Geek
CBG	Chemistry Board Game
CLE	Constructivist Learning Environment
CLO	Course Learning Outcome
CLT	Cognitive Load Theory
COPS	Compounds Organic Pathways Synthetic
CVI	Content Validity Index
DDR	Design and Development Research
FGT	Functional Group Transformation
GBL	Game-based Learning
ICT	Information and Communications Technology
ID	Instructional Design
I-CVI	Item-level Content Validity Index
JPU	Jadual Penentu Ujian
MOL	Mastering the Organic Chemistry Laboratory
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
PSPM	Peperiksaan Semester Program Matrikulasi

SLT	Student Learning Time
SME	Subject Matter Expertise
TIMSS	Trend in International Mathematics and Science Study
TIPs	Task Involving Play
TPACK	Technological Pedagogical Content Knowledge Model
ZPD	Zone of Proximal Development

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter, background of the study, problem statement, research objectives, research questions, significance of the study, limitation to the study and operational definitions will be discussed.

1.2 Background of the Study

Malaysian education system focused on acquiring knowledge, developing and expanding it through subjects such as Science, Mathematics and Languages. This has been the case for decades where ability to read, write and count among school children were the measurement of quality education delivered in educational institutes. However, current global education scenario deviates from what we had learnt by insisting on inculcating inquiry learning and higher order thinking skills among

children. Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) were two global assessments focusing on quality output by any education system (Ministry of Education, 2015). These assessment systems measured cognitive skills such as generating ideas and drawing conclusion based on what had been observed by the students.

PISA is a worldwide study by Organisation for Economic Co-Operation and Development (OECD) for member and non-membered nations that evaluates educational system by measuring 15-year-old school children's academic performance on reading, mathematics, and science. PISA began its survey in year 2000 and Malaysia had participated nine years after that. Based on PISA 2009 and 2012 report, Malaysian students' score were below the global average score of 494 in Mathematics, 496 in Reading, and 501 in Science (Chen, 2013). In year 2009, the score was 422 in Science and Malaysia ranked 55 out of 74 countries while in year 2012, the score dropped to 420 in Science and Malaysia ranked 52 out of 65 countries. The results from PISA survey showed that Malaysian students performed poorly especially in science subjects. Another assessment known as Trends in International Mathematics and Science Study (TIMSS) began its survey in 1995. It has been conducted every four years once for fourth grade and eight grade students. According to Malaysian Education Blueprint (2013-2025), Malaysia's performance in TIMSS eighth grade science declined every year since participating in the survey except year 2003. The result shows in year 1999, Malaysia's score was 492 and increased to 510 in year 2003. However, since then the score decreases to 471 and 426 in year 2007 and 2011, respectively. This international assessment which includes other countries such as Singapore, England, Hungary, and Japan comparatively showed Malaysia experiencing a drastic decline in the quality of

science education. According to Mullis and Martin 2017, content domains for eighth grade science emphasised on chemistry, an upgrade from fourth grade where students generally learned physical science (Mullins & Martin, 2017). In Malaysia, chemistry is taught at upper secondary school level beginning at the age of 16. The science stream package includes Physics and Biology as elective subjects together with Chemistry. Physical chemistry, organic chemistry and inorganic chemistry were three main branches of chemistry and in Malaysian schools, all three syllabuses were summarised into chemistry form four and form five textbook briefly. At macroscopic level, chemistry defined as what we can see and measure the materials of which our world made of (Chang, 2016).

Malaysian Matriculation system was introduced in 1999 with two different streams: arts and science streams. Back then, science stream students pursued their studies in two different modes consists of either Biology or Physics to complete the package which already had Mathematics, Chemistry, and English. Since 2011, the restructuring of matriculation program by Ministry of Education introduced three different modes for science stream students:

A. Module One – Mathematics, Chemistry, Physics, and Biology
B. Module Two – Mathematics, Chemistry, Physics, and Science Computer
C. Module Three – Mathematics, Chemistry, Biology, and Science Computer

Chemistry was one of the compulsory subjects for science and technical students in matriculation. So, students do have prior knowledge in chemistry since it had been taught in form four and form five schooldays. As students begin to pursue studies in matriculation, they will register physical chemistry in semester one and

organic chemistry in semester two. Topics taught in semester one and two based on Curriculum Specifications for Matriculation Chemistry are summarised in Table 1.1

Table 1.1

Summary of chemistry topics

Semester	Topics
I	Matter
	Atomic structure
	Periodic table
	Chemical bonding
	States of matter
	Chemical equilibrium
	Ionic equilibria
II	Reaction rate
	Thermochemistry
	Electrochemistry
	Introduction to organic chemistry
	Hydrocarbon
	Benzene and its derivatives
	Haloalkanes
	Alcohol
	Carbonyl compounds
	Carboxylic acid and its derivatives
	Amines
	Amino acids
	Polymers

Chemistry lessons in matriculation are conducted in three different modes: lecture, tutorial and practical. Lecture classes are conducted one hour per week while tutorial and practical classes for three hours and two hours per week, respectively. All the topics mentioned in Table 1.1 were covered by lecturers using these three different modes across eighteen weeks per semester in two semester system. Tutorial mode was main teaching and learning platform not only because it had more face-to-face contact hours with students but also most of the learning outcomes were covered here especially the one related to this research, organic chemistry synthetic pathways. Organic chemistry learnt in semester two matriculation studies was an important prior

knowledge for students who wish to pursue tertiary education in professional fields such as medicine, engineering, biotechnology, nutrition, biomedical, biochemical, environmental studies and many others.

Cha Jeongho, Kan Su-Yin and Chia Poh Wai (2018) claimed students at different academic stages developed negative perceptions in learning organic chemistry. Students always thought that organic chemistry is complex, hard and difficult. Most students found organic chemistry exceptionally challenging because of the breadth and depth of content and the rapid pace of the course, referring to it as "the infamous, dreaded 'orgo', a marathon of memorization (Paredes, Pennington, Pursell, Sloop, & Tsoi, 2010). Traditional chemistry curricula poses a major challenge to any educational reform effort that seeks to help students build connections between chemistry topics and courses as well as to integrate ideas within the discipline and across different scientific fields (Talanquer, 2018). Matriculation students faced huge challenges in understanding organic chemistry especially in three main scopes across the syllabus which were normally tested in *Peperiksaan Semester Program Matrikulasi (PSPM)* (Othman, Ibrahim & Talib, 2015). These scopes were organic molecular structure, organic chemistry reactions, and transfer of electrons (Othman *et al*., 2015).

Most notably, students found learning organic chemistry in semester two always challenging mentally than semester one and the trend was consistent regardless of the batches of students. Researcher believes improving students' interest in learning organic chemistry could be done by tapping the intrinsic motivation through alternative approach. The real problem of learning chemistry from educators' perspective though related to understanding how the students learn. Concepts introduced in chemistry cannot be linked by the students to their real life situations and they do not have a clue

how the progress had been made from simple chemistry theory (Johnstone, 2010). Thus, it was important as an educator, finding appropriate method or tool to facilitate learning chemistry in most effective way.

1.3 Problem Statement

Organic chemistry is one of the three main branches in chemistry that also includes physical chemistry and inorganic chemistry. Organic chemistry was unified by few broad themes where if these themes were understood by students, learning organic chemistry becomes much easier and rote memorization was minimised (McMurry, 2004). Process of learning organic chemistry involved few important concepts such as nomenclature and structure, functional groups, isomerism, symmetry and asymmetry, reaction arrows, and synthesis organic reactions. A deeper look particularly in matriculation perspective provided us with more difficult concepts like stereochemistry and retrosynthetic reactions. Duis (2011) summarised difficult concepts reported by organic chemistry educators (Table 1.2) with synthesis organic reactions among the hardest concepts in organic chemistry.

Table 1.2

Organic chemistry difficult concepts

Concepts	Number of responses
Reaction mechanisms	15
Acid base chemistry	12
Synthesis	9
Stereochemistry	9
Resonance (electron delocalization)	9
Molecular orbital theory	6
Spectroscopy	6
Polarity	6
S_N1, S_N2, E1, E2 reactions	5
Curved arrow formalism	5

Duis's findings was supported by Levy (2008) as cited in Talib, Nawawi, Ali, and Mahmud (2012) who claimed organic compound synthesis as one of the difficult concept perceived by students learning organic chemistry. Due to minimal understanding of basic organic synthesis, students faced problems in solving advanced organic synthesis questions especially interlinked retrosynthetic reactions (Carney, 2015). In another research, Teixeira and Holman (2008) reported that students not only struggle to solve multi-step synthetic pathways particularly retrosynthetic pathways but they found it hard to plan synthetic pathways as well. Besides that, students also often struggled to synthesise organic compounds especially when they were required to choose proper physical parameters such as temperature and catalyst (Triboni & Weber, 2018). In this case, students failed in determining correct chemical reagents to convert one organic compound to another. Furthermore, Farmer and Schuman (2016) claimed that students had difficulties with planning synthetic pathways because large amount organic reactions needed to be memorised.

From matriculation perspective, technical students who performed well in semester one (physical chemistry) need not necessarily produced same performance in semester two (organic chemistry) (Othman & Talib, 2015; Othman *et al*., 2015). Based on their Pearson correlation analysis, the researchers concluded that technical students faced more challenges in semester two due to abstract visualisation of organic chemistry compared to mathematical arithmetic of physical chemistry. Results of the study showed that students' understanding of organic chemistry still at low level and only excellent students recorded higher score due to strong pre-requisite knowledge in organic chemistry. In semester two, main challenges come from organic chemistry because paper one and paper two *Peperiksaan Semester Program Matrikulasi (PSPM)* Chemistry has higher percentage of organic questions compared to physical chemistry; 73% and 65% in paper one and paper two, respectively. Nevertheless, synthetic pathways learnt across semester two chemistry make either part of organic questions or the questions itself in PSPM semester two. Generally, matriculation students struggled in solving synthetic pathways questions because they do not have enough exposure to organic reactions in a format that facilitates retrosynthetic problem solving although it has been introduced during lecture or tutorial classes.

The inability of learners to write or complete synthetic organic routes addressed by researchers worldwide with different strategies like using mind map or road map (Schaller, Graham, & Jones, 2014), web-based leaning (Emre, Daat, Austin & Gould, 2016), and learning via cell phone (Pursell, 2009). Road map developed to improve students' visualisation and to study inter-relationships between organic compounds. However, road map does not enhance skills of students planning and carrying out retrosynthetic reactions. In a separate research, web-based learning developed to

provide undergraduate students an online environment in writing and practising retrosynthetic organic reactions. Although student's motivation was found to be improved using web-based learning, however, lack of online assess in matriculation colleges could deter this strategy. Besides that, web-based learning recorded highest online learning for those students with strong self-determination (Emre *et al*., 2016). The rest of the students must be ensured to participate in online learning by the teachers or lecturers. In addition to this, learning organic reactions using cell phone was proposed according to the current trend and learning style of millennial generation. Versatility of cell phone with various uses like watching videos, listening to music, playing games, and searching for information gave the researcher an idea of developing cell phone flashcards emphasising on organic chemistry. However, results of the research showed that students agreed cell phone strategy improves their learning on organic reactions but not synthetic routes (Pursell, 2009).

Therefore, a comprehensive solution was required to address the issue of learning synthetic pathways since previous approaches suggested had its weaknesses in implementation particularly in matriculation perspective. Thus, researcher planned to use an approach that draws attention of current generation learners; game-based learning (GBL). According to Alexander (2008), using games in chemistry classroom provided engaging and alternative methods of instruction. Games were excellent methods of experiential learning and had been used at various education levels like high schools (Silva & Ribeiro, 2017) and universities (Farmer & Schuman, 2016; Knudtson, 2015; Winter, Wentzel, & Ahluwalia, 2016) to enliven chemistry lessons. Games were also excellent for reviews, practices and just fun. Furthermore, according to Kangas,

Koskinen and Krokfors (2016), integration of games in teaching still considered as unexplored area of study worldwide.

In order to justify suitability of this idea in learning organic chemistry synthetic pathways, the researcher of this study developed a needs analysis questionnaire using Google Forms which were distributed to 36 educators consists of form six chemistry teachers and matriculation lecturers from chemistry unit. Based on the feedback from needs analysis survey, researcher of this study believed that an educational game can serve as pedagogical tool which suits very well with characteristics of current generation students whom prefer to construct learning at their very own pace and actively engaged with their peers (Kordaki, 2015; Rastegarpour & Marashi, 2012; Selvi & Çoşan, 2018; Tuomisto, 2016). However, it was important to note some of these games (Angelin & Ramström, 2010; Cha et al., 2018; Gogal, Heuett, & Jaber, 2017; Knudtson, 2015; Silva & Ribeiro, 2017; Teixeira & Holman, 2008) used only memorisation and drilling gaming elements by denying strategic gameplay which lead to boring mood over a period of time. During a gameplay, students should be involved in cycle of actions and reflections. This can be achieved when gaming elements developed based on Task Involving Play (TIPs) (Triboni & Weber, 2018).

Students who used educational games during learning session especially in organic chemical reaction improved adequately and the positive feedbacks from them showed the effectiveness of these games (Triboni & Weber, 2018). Among those educational games developed, board type games had improved cognitive learning and critical thinking of the learners (Wardani, Lindawati, & Kusuma, 2017), provided learners with experience to draw knowledge (Boghian, Cojocariu, Popescu, & Mata, 2019), created social nature in the game that allows students to learn in cooperative

scenario (Esdras *et al*., 2019), built leisure activities filled with challenges (Alfaifi, 2013), and required little additional preparation time (Mosher, Mosher, & Garoutte, 2012). Thus, researcher of this study proposed development of a board game consists of various organic chemical routes connected in retrosynthetic reactions. The game was designed using ADDIE model as the platform with learning theories such as constructivist learning theory and experiential learning embedded into it.

In synthesis organic reactions, there was no comprehensive game that relates organic compounds via synthetic routes or retrosynthetic routes. Majority of the games mentioned previously catered for undergraduate students and less suitable for matriculation or pre-university students as they learnt lesser number of reactions. This means the previously developed games can be played by learners perhaps in the initial stage or during certain stage only. Limitations to strategic gameplay particularly board game involving organic chemistry had lead the researcher to an idea of developing COPS board game. It was taught and shared to matriculation chemistry lecturers to gather students' perceptions on impact of COPS board game in learning organic chemistry synthetic pathways. Researcher believes that COPS board game will help students learn synthetic pathways comprehensively and allow them to use strategic gameplay during transformation of one homologous series to another.

1.4 Research Objectives

Based on the background of the study and problem statement, this research was conducted to:

a. develop an organic chemistry educational game, COPS board game for learning organic synthetic pathways.

b. evaluate validity of the COPS board game.

c. evaluate reliability of the COPS board game.

d. evaluate student's perceptions on goals, board design, board organisation, playability, and usability of COPS board game.

1.5 Research Questions

This research was conducted to answer the following research questions which were related to development of COPS board game and users' perceptions after playing it.

a. What are the steps involved in development of the COPS board game?

b. What is the validity coefficient level of the COPS board game?

c. What is the reliability coefficient of the COPS board game?

d. What are the students' perceptions mean score on goals, board design, board organisation, playability, and usability of COPS board game?

1.6 Conceptual Framework

According to Adom, Hussein, and Joe (2018), conceptual framework was an explanation of how the research problem would be explored. It was representation of concepts and variables in research. The concepts involved in this study were learning theories, Keller's ARCS model, GBL, and ADDIE model. Learning theories used in

designing COPS board game were behaviourism, constructivism, cognitive constructivism, social constructivism, experiential learning, and flow state theory while learning activities designed using Gagne's Nine Event of Instruction. Literature reviews showed inclusion of all these theories and concepts as an important base for developing educational game (Boghian et al., 2019; Ibrahim & Jaafar, 2009; Plass, Homer, & Kinzer, 2015; Tuomisto, 2016; Westera, 2015). Learning activities in incremental learning steps ensured knowledge transmitted systematically according to learner's cognitive ability. Finally, COPS board game was validated by panel of five experts and its reliability was determined during pilot test.

Conceptual framework for this study was based on ADDIE model. In the first phase, researcher conducted needs analysis survey on 36 chemistry teachers and lecturers to gather information on suitability of GBL in learning organic chemistry synthetic pathways. In addition to that, a deep literature review across various disciplines such as chemistry particularly organic chemistry, psychology, information technology, and instructional design methods were studied to find the research gaps for this study. Then in the next phase, results of needs analysis survey and research gaps from literature reviews were used for designing and developing COPS board game. Developed game was used during learning session to teach organic chemistry synthetic pathways or retrosynthetic reactions. Subsequently, COPS board game was implemented in real study after training sessions with teachers or facilitators and learners. Finally, evaluation phase was conducted by measuring student's performances in formative and summative assessment prepared by researcher.

A purposeful framework was viewed as an investigation map for the researcher on how to conduct the study and measure the determined variables (Adom *et al*., 2018).

A researcher needs to identify the variables involved in his research and its relationship with learning theories, instructional design models, and constructs leads to construction of a conceptual framework. In this research, variable measured was students' perception on developed COPS board game under five constructs of goals or objectives, board design, board organisation, playability, and usability. Then, research instruments such as questionnaires and validation form were validated by panel of three education experts. Meanwhile, COPS board game validated by panel of five experts consists of subject matter expertise (SME) and game experts. Next, a pilot test was conducted with respondents having similar characteristic to real study sample. Purpose of the pilot survey was to determine reliability coefficient of the board game and Cronbach's alpha value of student's perceptions questionnaire. Figure 1.1 shows conceptual framework for this research.

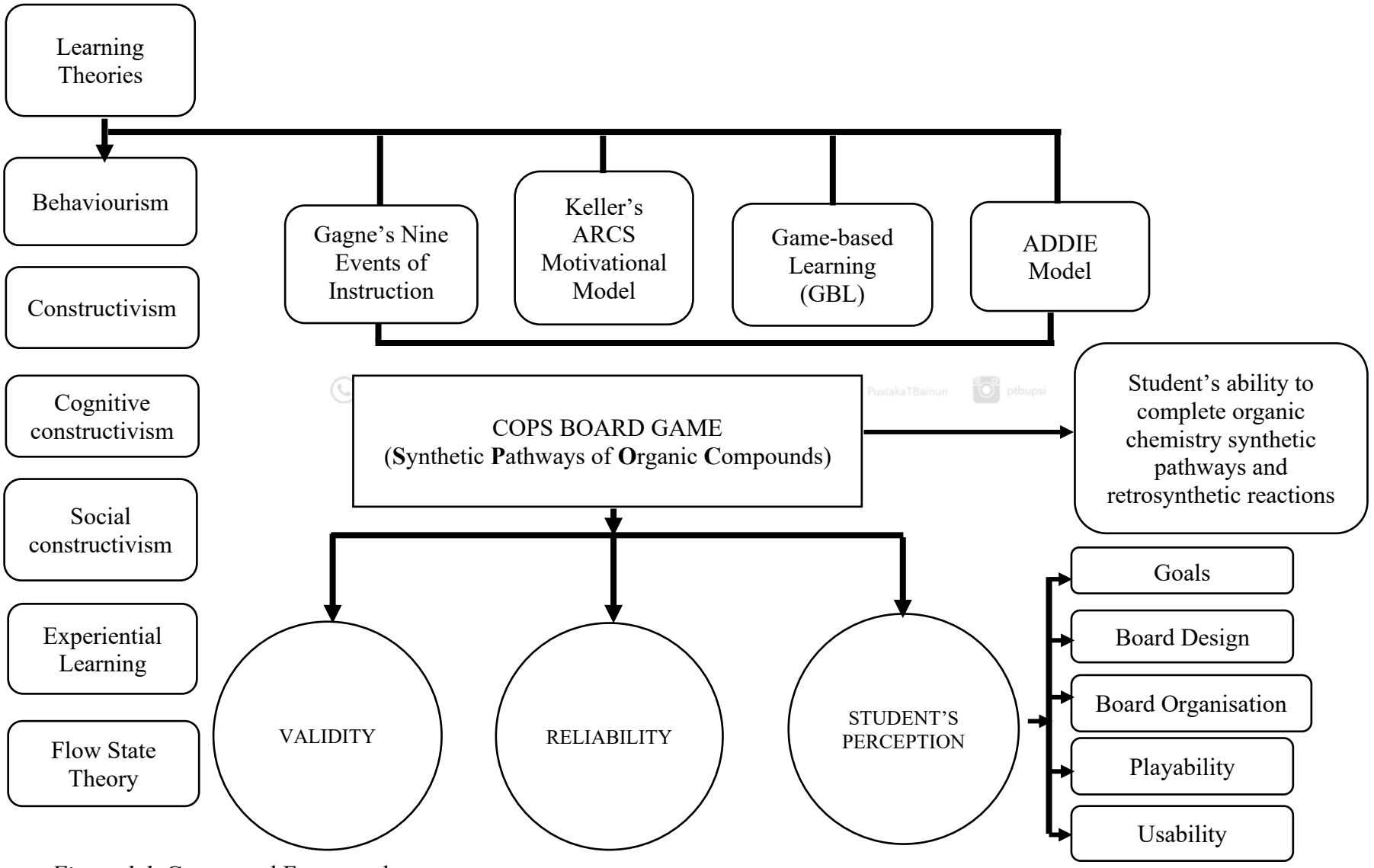

Figure 1.1. Conceptual Framework

1.7 Significance of the Study

This research conducted with hopes of bringing beneficial to four parties consists of teachers, students, researcher of this study as well as to the process of teaching and learning in organic chemistry synthetic pathways.

1.7.1 Teachers

In teachers' perspective, this study gave them an alternative tool to assist teaching and learning process possibly in much higher level of Bloom's Taxonomy as well as to assess students' understanding in organic chemistry. Teachers had to do more than just delivering content from book where the huge challenge was engaging student's world with world of information (Alfaifi, 2013). Teachers use COPS board game to encourage more retrosynthetic thinking on organic routes among students because most of the time students preferred simple chemical routes only. A fun and exciting game has the ability to connect students with knowledge that need to be perceived. Hence, COPS board game provides that platform for teachers to deliver the content intended in a form accepted and liked by the students.

1.7.2 Students

Development of COPS board game is significant to matriculation students in enhancing their interest on learning organic chemistry synthetic pathways via game-based learning

approach. Students assumed role as active learners during teaching and learning session and their involvements are a reflection of their motivation to participate in COPS board game. Su and Cheng (2015) claimed that students attained higher learning motivation which lead to higher learning achievement when a game designed in such way that arouses their curiosity and interest. COPS board game was developed based on matriculation organic chemistry syllabus emphasising on synthetic pathways. It was designed by the researcher in accordance with the questions frequently asked in PSPM Chemistry paper one and paper two as explained in section 1.3. Apart from set induction phase of formal organic chemistry lessons, COPS board game also can be played to strengthen and deepened organic chemistry synthetic pathways knowledge and problem-solving skills during desired content mastery or at the end of the lessons. Besides that, during the gameplay, students can used COPS board game as corrective step for any misconceptions like choosing wrong chemical reagents or physical conditions for a particular organic reaction (Triboni & Weber, 2018). For example, student wrote bromination of benzene ring using bromine in the presence of sunlight instead of using bromine in iron (III) chloride which showed the misconception.

1.7.3 Researcher

In this study, researcher aimed at developing a comprehensive educational game in organic chemistry synthetic pathways which involves strategic gameplay that allows students to interact and intrinsically motivated in learning process. Hence, researcher used an instructional design model called ADDIE for systematic development of an education tool to mirror conventional teaching and learning process.

1.7.4 Teaching and Learning Process

COPS board game, an integration of educational learning theories such as behaviourism, cognitive constructivism, and social constructivism functionally elevated the teaching and learning process of organic chemistry synthetic pathways. The medium prepared allows students to have meaningful learning experiences either inside or outside the classroom. Students neither bored nor anxious in learning organic chemistry synthetic pathways while playing COPS board game and this created a fun and interactive learning environment where researcher strongly believes motivation of learners' will be triggered. Advantages of using GBL approach had risen to the idea of developing COPS board game. For instance, GBL demanded problem-solving skills and provided realistic practices (Triboni & Weber, 2018) during gameplay which directly influenced the learning process. GBL also helped build social-skills, improve learner's motivation and attitudes (Gunter, Kenny, & Vick, 2008) as well as brought sense of achievement upon completing specific learning objectives. Therefore, researcher developed educational game to maximise organic chemistry learning potential among students and at the same time, to overcome weaknesses in other approaches from matriculation perspective as mentioned in section 1.3, problem statement. Furthermore, this study gave an opportunity to the researcher to fill the gap found in previous organic chemistry synthetic pathways literatures.

1.8 Limitation of the Study

There were some limitations emphasised in this study. Firstly, respondents for this research were students from one of the fifteen matriculation colleges in Malaysia whom pursuing their studies in science stream. Thus, the findings of the research cannot be generalised. COPS board game was developed to solve synthetic pathways problems which was part of organic chemistry learned in semester two. Synthetic pathways were so important to understand conversion of one homologous series to another and vice versa. However, development of COPS board game only focuses certain homologous series like alkene, alcohol, and haloalkane. Benzene, carbonyl compounds, and carboxylic acids are not included during game content design phase. In addition, other organic chemistry components like reactions mechanisms and physical properties of organic compounds tested in matriculation examinations are also not included in this research. This is due to unsuitability of GBL approach in learning reactions mechanisms and physical properties. Reaction mechanisms are better learned using animation or simulations (Talib *et al*., 2012) while physical properties using Thinking-based learning (TBL). Time management is another limitation. Time provided by the researcher for playing COPS board game is based on time allocated in official timetable by college administration. So, when teachers use COPS board game in teaching and learning session, gameplay might be dragged longer than expected because it involves low achievers who need more time to perform tasks in the game.

1.9 Operational Definition

Several terms were used throughout this research, and they were defined as the following:

1.9.1 Validity

According to Heale and Twycross (2015), validity was defined as ability of a research instrument to measure domains related to constructs and the extent to which a concept was accurately measured in a quantitative study. Peters, Vissers, and Heijne (1998) claimed concept of validity can be referred as content validity of measurement instruments. According to Hummel, Joosten-ten Brinke, Nadolski, and Baartman, (2017), validity of game was basically checked on whether game content aligns with learning objectives or outcomes of subject matter and learning activities within the game. Thus, in this study, game validity referred to percent of agreement from panel experts on suitability of COPS board game with subject matter, organic chemistry. To determine the validity coefficient of COPS board game, a validity form was built with three constructs and 46 items. The three constructs which were adapted from TPACK (Technological Pedagogical Content Knowledge**)** model consists of content, pedagogy and technology (Schmidt *et al*., 2009). These constructs emphasised on blending both content and pedagogy knowledge with aim to develop better teaching methods of desired content. Meanwhile items for each construct were adapted from Chung, Mak, Suen, and Sze (1996), Gutierrez (2014), and Schmidt *et al*. (2009). Then, the constructed research instrument together with developed COPS board game were given

to panel of experts to ensure all the gaming elements and its content suitable as well as meeting objectives of the study (Abdullah & Wei, 2017).

1.9.2 Reliability

According to Heale and Twycross (2015), reliability or consistency of measure referred to having almost same responses each time a survey was completed. In this study, reliability coefficient was determined from Cronbach's alpha value after Statistical Package for the Social Sciences (SPSS) analysis. From COPS board game perspective, reliability of the game referred to students' learning experiences through designed learning activities (Rahman, 2016). Cronbach's alpha value for COPS board game was calculated after completion of pilot test. The accepted Cronbach's alpha value was 0.7 and higher (Heale & Twycross, 2015). To measure the reliability coefficient of COPS board game, a reliability questionnaire was built with 16 items that emphasised on the game's learning activities. It clearly stated on what the students learnt and how do they achieve it while playing COPS board game. In this study, the instructional goal was considered achieved when students were being able to complete organic chemistry synthetic pathways or retrosynthetic reactions correctly. This instructional goal was determined from classroom observations, interviews, and formative assessments with students during learning organic chemistry synthetic pathways throughout entire semester two.

1.9.3 Perception

Perception is the way in which something is regarded, understood or interpreted. Perception is considered as count noun (many perceptions) rather than mass noun. According to Tan (2010), mass noun was ability to hear, see or become aware through senses similar to human perception which not suitable in research contexts. In this study, perception refers to students' perceptions on using COPS board game as learning tool for studying organic chemistry synthetic pathways. To measure student's perceptions on COPS board game, a questionnaire was built with five constructs and 36 items. The five constructs were goals, board design, board organisation, playability, and usability. In this study, learning goals or objectives were defined as specific purposes (Alfaifi, 2013) on why COPS board game was built. For example, COPS board game was built to encourage discussion and interaction on organic chemistry synthetic pathways among students. Board design was defined as design of materials such as board and various cards used in developing COPS board game. Meanwhile board organisation referred to organising gameplay in COPS board game which includes distribution of number of cards, playing time and understanding instructions. Playability was defined as principles concerning the game that were integrated in game design (Esdras *et al*., 2019). For example, chances of succeeding in a game was equal to all the players. Usability in COPS board game was defined as the usefulness of the board game in helping students learn organic chemistry synthetic pathways.

1.9.4 Board Games

A board game is a tablet top game that involves counters or pieces moved or placed according to a set of rules on a pre-marked surface called board. Alfaifi (2013) claimed board game allowed learners to become decision makers in engaging and challenging learning environment to solve problems. Some games were based on pure strategy, but many contain an element of chance; and some are purely chance, with no element of skill. Board games were often developed as an indoor game which was defined as games that played in close doors or inside a space, away from any interferences like unpredictable weather. Indoor games were normally limited to tabletop games and played in small areas. Board game for this study was called COPS. Alphabet C refers to Compound, O refers to Organic, P refers to Pathways and S refer to Synthetic. COPS were written in reverse for Synthetic Pathways of Organic Compounds as representation to inclusion of certain reversible organic pathways. For example, forward synthetic pathway for producing alcohol was known as hydration while backward synthetic pathway for the same route was known as dehydration.

1.9.5 Synthetic Pathways

Organic reactions refer to all the organic chemical reactions learnt across ten organic chemistry topics in semester two under chemistry syllabus related to matriculation. This reactions inclusive of reagents, physical conditions such as temperature and catalyst, and formation of particular products via mentioned reaction (Matrikulasi, 2018). In this study, synthetic pathways are generated as a result of combination of many simple

chemical routes in retrosynthetic form. For example, synthetic pathway to produce carboxylic acid begins with a haloalkane.

$$CH_3Br + NaCN \longrightarrow CH_3CN + H_2O/H^+ \longrightarrow CH_3COOH$$

1.10 Conclusion

Many teaching methods have been introduced in classroom practice to enhance students' learning process of chemistry especially in organic chemistry. Educators should prepare, see themselves in a new challenging role, and find alternative approaches or solutions to tackle issues in learning organic chemistry in classroom contexts. Generally, these approaches should be able to increase students' interest and motivation in learning various organic chemistry concepts. One of the popular approaches was using GBL as it creates more excitement and fun in learning via games. Thus, researcher of this study proposed a board game called COPS as an alternative approach in teaching and learning organic chemistry synthetic pathways. COPS board game acted as a useful tool in helping matriculation students in answering, writing, and completing synthetic pathways type of questions in PSPM semester two as well as a good teaching tool for the chemistry educators.