DEVELOPMENT AND THE EFFECT OF MOBILE ENTHALPY GAME APPLICATION ON MATRICULATION STUDENTS' ACHIEVEMENT IN THERMOCHEMICAL EQUATION

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SULTAN IDRIS EDUCATION UNIVERSITY

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DEVELOPMENT AND THE EFFECT OF MOBILE ENTHALPY GAME APPLICATION ON MATRICULATION STUDENTS' ACHIEVEMENT IN THERMOCHEMICAL EQUATION

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ABSTRACT

The purpose of this study is to develop a mobile enthalpy game application (MEGA) and study its effect on matriculation students' achievement in writing thermochemical equations. MEGA is an Android game application developed for student to acquire skills to write thermochemical equations. It is developed based on ADDIE's, Kwon's and the game-based learning engineering models. MEGA was validated in terms of content, pedagogy and multimedia by using Cohen's kappa agreement coefficient. Reliability of MEGA is determined by using the reliability coefficient. This quantitative study employed time-series quasi experimental design involving 36 students in the control group (PowerPoint slides) and 36 students in the experimental group (MEGA). Samples are chosen by using a simple random sampling technique. The effect of MEGA versus PowerPoint slides on student achievement of thermochemical equation were compared. Data was collected by using a need analysis questionnaire, pre-tests, post-tests, game score sheets and evaluation forms. Data were analyzed descriptively by using percentage and inferentially using t-test and Pearson correlation analysis. Findings showed the Cohen's kappa agreement for content is 1.00, pedagogy is 1.00 and multimedia is 0.82. Meanwhile, the reliability coefficient for MEGA is 0.71. Results showed there were no significant differences in pre-test scores between control and experimental groups. There were significant differences between pre and post-test scores for control group and experimental group. There was also significant difference in the post-test scores between control and experimental groups. In conclusion, MEGA could enhance students' achievement in writing thermochemical equations compared to the PowerPoint slide presentation. This study implies, in this era of Education 4.0, mobile game applications (MEGA) could promote gen Z learning of chemistry.

PEMBANGUNAN DAN KESAN APLIKASI PERMAINAN MUDAH ALIH ENTALPI KE ATAS PENCAPAIAN PELAJAR MATRIKULASI DALAM PERSAMAAN TERMOKIMIA

ABSTRAK

Tujuan kajian ini adalah untuk membangunkan aplikasi permainan mudah alih entalpi (MEGA) serta mengkaji kesannya terhadap pencapaian pelajar matrikulasi dalam menulis persamaan termokimia. MEGA ialah aplikasi permainan Android yang dibangunkan untuk pelajar memperoleh kemahiran menulis persamaan termokimia. MEGA dibangunkan berdasarkan Model ADDIE, Kwon serta Model pembelajaran permainan digital. MEGA disahkan dari segi kandungan, pedagogi serta multimedia dengan menggunakan pekali persetujuan Cohen kappa. Kebolehpercayaan MEGA ditentukan dengan menggunakan pekali kebolehpercayaan. Kajian kuantitatif ini menggunakan reka bentuk eksperimen kuasi siri-masa dengan melibatkan 36 orang pelajar dalam kumpulan kawalan (slaid *PowerPoint*) dan 36 orang pelajar dalam kumpulan eksperimen (MEGA). Sampel dipilih dengan menggunakan teknik persampelan rawak mudah. Kesan MEGA dan slaid *PowerPoint* terhadap pencapaian persamaan termokimia pelajar dibandingkan. Data dikumpul dengan menggunakan soal selidik analisis keperluan, praujian, pascaujian, helaian markah permainan dan borang penilaian. Data dianalisis secara deskriptif dengan menggunakan peratus dan secara inferensi dengan menggunakan ujian-t dan korelasi Pearson. Hasil kajian menunjukkan pekali persetujuan Cohen kappa bagi kesahan kandungan ialah 1.00, pedagogi ialah 1.00 dan multimedia 0.82. Di samping itu, kebolehpercayaan MEGA ialah 0.71. Hasil dapatan menunjukkan tidak terdapat perbezaan yang signifikan dalam markah praujian antara kumpulan kawalan dan kumpulan rawatan. Terdapat perbezaan yang signifikan dalam markah praujian dan pascaujian bagi kedua-dua kumpulan. Terdapat juga perbezaan yang signifikan dalam markah pascaujian bagi kumpulan eksperimen berbanding kumpulan kawalan. Kesimpulannya, MEGA dapat meningkatkan pencapaian pelajar dalam menulis persamaan termokimia berbanding persembahan slaid *PowerPoint*. Implikasi kajian menunjukkan di era Pendidikan 4.0 ini, applikasi permainan mudahalih seperti MEGA mampu meningkatkan pembelajaran generasi Gen-Z dalam subjek kimia.

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LIST OF ABBREVIATION

ADDIE	Analysis, Design, Development, Implementation and evaluation
EPRD	Department of Educational Planning and Research Malaysia
GBL	Game-based learning
ICT	Information Communication and Technology
IR	Industrial Revolution
MEGA	Mobile Enthalpy Game Application
MoE	Ministry of Education
SME	Subject Matter Expert
SPM	Malaysian Certificate of Education
SPSS	Statistical Packages for Social Science

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the 21st century, Malaysia has faced many challenges. The rapid development of Information and Communication Technology (ICT) has invited the industrial revolution. Currently, Malaysia is facing Industrial Revolution 4.0 (IR 4.0). Many jobs were being taken over by Artificial Intelligence (AI) and automation. Consequently, IR 4.0 has demanded its future worker be highly knowledgeable, skillful, and creative. The matriculation education system must adapt its curriculum and delivery method according to this global change to produce graduates that are competent and can fill in newly emerging jobs.

The development of ICT has leverage technology as a teaching tool in the classroom to improve the learning quality of students (Ministry of Education, 2013). According to Malaysia Education Blueprint 2013-2025, educators are encouraged to maximize the use of ICT for distance and self-paced learning. The self-paced learning supported by mobile technology is highly recommended because learning activities become more personalized, engaging, flexible, and effective (Bartolomé, Castañeda, & Adell, 2018). Students could learn more effectively with the guidance, hints, supportive tools provided in the mobile game application. The mobile game application could transform teaching and learning activities in the classroom becomes more student-centered. However, educators feel a challenge when they need to design a lesson involving a new generation of matriculation students with the use of technology.

Students nowadays are Gen Z generation (Noor Azman Othman, Mas Anom Abdul Rashid, Ida Rosnita Ismail, Saifulrizan Norizan, Sarah Artiqah Mohamad Saad, 2019; Prensky, 2001). They are familiar with the use of mobile devices in their daily life activities from a very early age (Rubijesmin Abdul Latif, 2007; Hasiah Mohamed, Nora Yanti Che Jan, & Nik Marsyahariani Nik Daud, 2010). Gen Z is looking forward to the use of mobile devices to address their weaknesses in academic. They are highly attracted to digital games as they viewed learning as playing. Hence, mobile game application is a good option for teachers to apply self-paced learning among Gen Z. Gen Z could learn chemistry lessons in a more interesting, fun, and stress-free atmosphere.

1.2 Background of the Study

Malaysian matriculation program is a foundation course offered by the Ministry of Education to students who want to pursue their studies at university after secondary school. Matriculation Programmes in Malaysia intended to produce students who are knowledgeable, creative, and competitive in science, technology, and professional fields (Matriculation Division, 2017).

Generally, there are two types of matriculation programmes, namely a one-year matriculation programme and a two-year matriculation programme. Three modules are employed in Malaysia matriculation programmes:

- Module 1: students need to study all pure science subjects, such as Chemistry, Biology, Physics, and Mathematics
- Module 2: students need to study Chemistry, Physics, Mathematics and Computer Science (no Biology subject)
- Module 3: students only study Chemistry, Biology, Mathematics and Computer Science subject (no Physics subject)

Chemistry subject is compulsory in all Science Matriculation Programme. Chemistry is important in matriculation as it prepares students with basic concepts, principles, and science skills in handling laboratory apparatus and chemicals (Matriculation Division, 2018). Students will be able to solve chemistry and technology problems in their daily life if they acquire chemistry literacy from studying chemistry. There are three main teaching and learning strategies in matriculation college: lecture,

tutorial, and practical. Matriculation in Malaysia is a fast track learning system. All of the course contents need to be completed before the final examination at the end of the semester.

Overall, there are thirteen chapters that need to be completed in semester two of the matriculation syllabus (Matriculation Division, 2018). All chapters are illustrated in Table 1.1. Three chapters focus on learning physical chemistry whereas the following ten chapters focus on learning organic chemistry.

Table 1.1

Chapters in Chemistry Subject of Matriculation Syllabus

Chapter
Reaction Kinetics
Thermochemistry
Electrochemistry
Introduction to Organic Chemistry
Hydrocarbons
Benzene and Its Derivatives
Haloalkanes (Alkyl halides)
Hydroxy Compounds
Carbonyl compounds
Carboxylic Acids and Its Derivatives
Amines
Amino Acids
Polymers

Students perceived physical chemistry topic is challenging and abstract due to highly use of symbolic language in the subject (Adesoji, Omilani, & Dada, 2017; Fox & Roehrig, 2015; Nyachwaya & Wood, 2014). In chemistry, symbolic languages are used to explain microscopic behaviour of molecules which is invisible. Since students

are hard to imagine the molecular interaction so they could not describe it meaningfully using symbolic language and apply it to solve chemistry problems (Cai, Wang & Chiang, 2014; Hodges, Wang, Lee, Cohen, & Jang, 2018; Karacop & Doymus, 2013). As a result, many misconceptions existed.

According to Hafsah Taha, Rosnani Hashim., Zurida Ismail., Kamaruzaman Jusoff., and Khoo (2014), the learning problems of students in chemistry not only contribute by content but also other factors such as teacher-centered pedagogies, student's conceptual understanding, and lacking teaching and learning resources. As a result, student-centered teaching is highly recommended by the Ministry of Education such as experiment, discussion, simulation, project, field trips, and the use of technology (Ministry of Education, 2005).

The learning process becomes more active and fun with mobile game applications. Playing mobile game application could train students to analyse the problem, reflecting on their knowledge, making a connection, and mastering problem-solving skills (Antunes, Pacheco, & Giovanela, 2012; Cojocariu & Boghian, 2014; Crimmins & Midkiff, 2017; Erhel & Jamet, 2013; Hoffman & Nadelson, 2009; Hwang, Shih, Ma, Shadiev, & Chen, 2016; Kim, Park, & Baek, 2009; Simpson & Elias, 2011; Tsai, Tsai, & Lin, 2015; Yang, 2012). This could enhance a student's understanding of abstract chemistry concepts. Consequently, their achievement in chemistry subject could be improved. According to literature (Da Silva Júnior *et al*., 2018; Holmes, 2012; Kavak, 2012; Sousa Lima *et.al*., 2019), the game could be one of the alternative teaching strategies in classroom lesson to improve student's achievement.

1.3 Statement of Problems

From a need analysis study, matriculation students are found weak in writing a thermochemical equation. They are unable to do some simple calculation of enthalpy by using a mole of reactant or products according to the definition for a different type of enthalpy reaction. The student's problems in writing a thermochemical equation could be shown in their quiz answer in Figure 1.1.

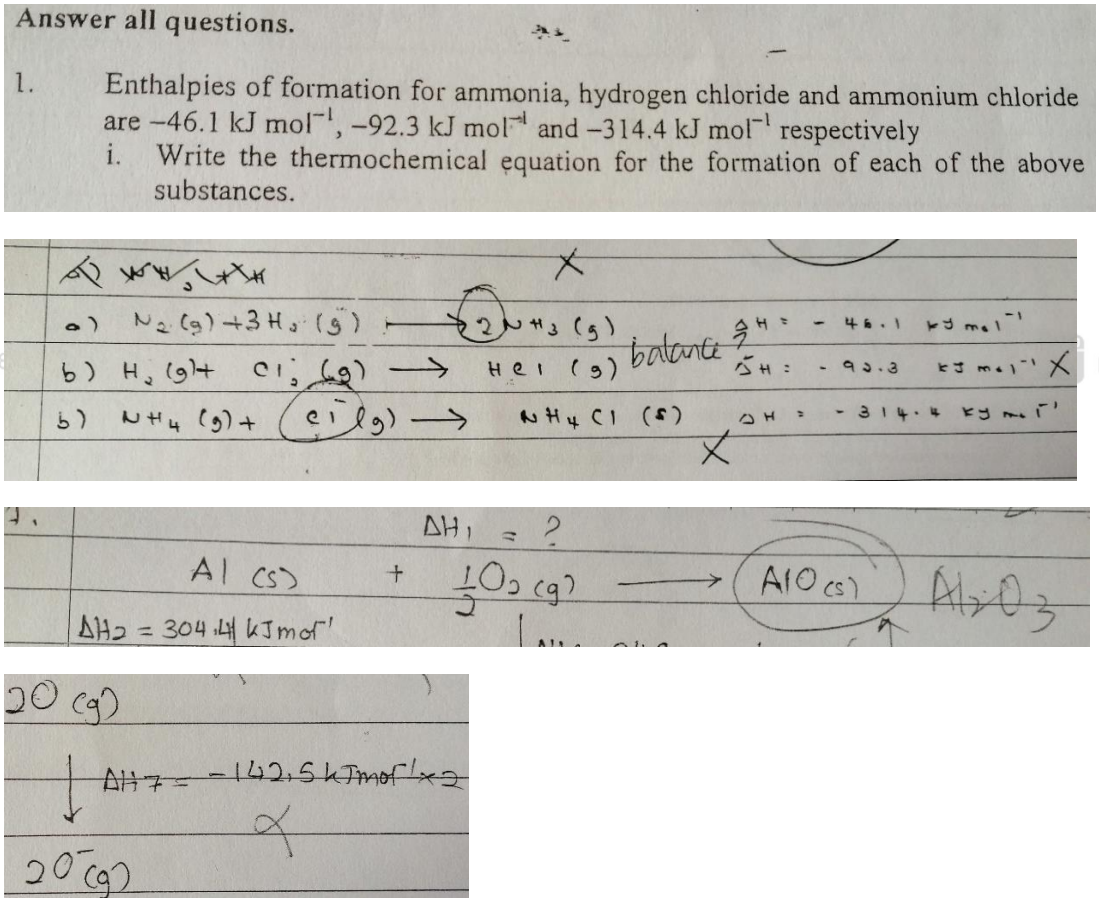

Figure 1.1. Matriculation Student's Quiz Answer for Thermochemical Equation

From the quiz, students are confused with reactant and product in the thermochemical equation either involving ion, neutral atoms, or molecules. As an example, the product of dissociation of solid ionic salt is written as neutral atoms rather

than corresponding ions (Naah & Sanger, 2012). Baah and Ampiah (2012) also reported chemical reaction equations written by students are not balanced because they fail to determine products of reactions. Imbalanced chemical equation has caused the student's difficulty in determining the value of enthalpy. Student's problems might be closely related to their poor understanding of stoichiometry and mole concept (Hafsah Taha *et al*., 2014). This is because the value of enthalpy depends on the mole quantity of reactant or product according to the definition of enthalpy for different chemical processes. Hence, to write the thermochemical equation correctly, students need to acquire both conceptual and algorithmic understanding (Sreenivasulu & Subramaniam, 2013).

Besides, students are found unable to transform reactions statements given in questions into corresponding chemical symbols and equations. Students tend to write the wrong molecular formula even though the International Union of Pure and Applied Chemistry (IUPAC) name are given. Writing a molecular formula is challenging as it is abstract and required a specific encoding process (Taskin & Bernholt, 2014). Students are found confused with Roman numerals in brackets of IUPAC names, unable to write correct formulae of cations, anions, and combine both to form neutral ionic compounds (Baah & Anthony-Krueger, 2012). All of the problems mentioned might due to lacking knowledge about the valency of the electron with stability atoms or molecules arrangement. Educators feel challenge when teaching the thermochemical equation as students are facing misconceptions when writing thermochemical equations.

The misconceptions faced by students include stoichiometry ratios, coefficient errors, stoichiometric calculations using the mole concept and subscript confusion,

dissociation of polyatomic ion, enthalpy, and balancing chemical equations (Naah & Sanger, 2012; Sanger, 2005; Yitbarek, 2011). Both coefficient and subscripts in the chemical equation are used interchangeably (Naah & Sanger, 2012; Taskin & Bernholt, 2014).

Besides thermochemical equations, students faced misconceptions in learning Thermochemistry (Wiji & Mulyani, 2018). The misconceptions include (a) enthalpy change does not depend on phase reactants and products (b) sign (+) and (-) not affecting the calculation and value enthalpy change; (c) standard enthalpies change same with enthalpies change; (d) ΔH reaction = ΔH_f reactants – ΔH_f products; (e) ΔH reaction = ΔH_f reactants +ΔH_f products; (f) ΔH reaction does not depend on the number of substances that reacts; (g) ΔH reaction obtained will be different if using different ways. Consequently, most of the matriculation students do not include phase when writing the thermochemical equation. The enthalpy changes of reaction are written regardless of the number of substances reacts.

The presence of misconception among students is due to their failure in mind processing and making a deeper connection between chemistry concepts and reality (Chandrasegaran, Treagust & Mocerino, 2007; Johnstone, 1991; Rastegarpour & Marashi, 2011; Triboni & Weber, 2018). The misconception in chemistry topics must be addressed properly because it will block scientific findings and resistant to conceptual change in learning subsequent chemistry concepts (Nik Syaharudin Nik Daud, Mohd Mustamam Abd Karim, Siti Wan Noraini Wan Hassan, & Nurulhuda Abdul Rahman, 2015). Therefore, teaching and learning techniques should be modified to address misconceptions faced by matriculation students.

Besides, students complained that there are too many terminologies, processes, equations, and formulas that need to be memorised as they study the entire subtopic. Students lack conceptual understanding when studying thermochemical equations (Wan Fatimah Wan Ahmad, & Nabil Fikri Abdul Rahman, 2014). When students see Thermochemistry as hard and not understandable, their achievement in Chemistry subject will deteriorate. This is because most of the matriculation past year examination question on Thermochemistry grounded on thermochemical equations. Students will lose many marks in the examination if they are unable to write the thermochemical equation correctly. Therefore, students are necessary to acquire skills in writing the thermochemical equation. An alternative teaching method is needed to improve student's achievement in writing the thermochemical equation.

Most of the materials used for teaching and learning thermochemical equations were module, worksheet, textbook with CD-ROMs, simulation, multimedia courseware, interactive multimedia, and web-based learning tools (Kulkarni & Tambade, 2013). The mobile game application is not as popular as a supporting tool to teach the thermochemical equation. Although there is much chemistry mobile game application designed such as *Chairs* (Winter, Wentzel & Ahluwalia, 2016), *alkamia* (Wan Fatimah Wan Ahmad, & Nabil Fikri Abdul Rahman, 2014), *brainchemist* (Romiyatun, 2014), *atomob* (Cahyana, Paristiowati & Fauziyah, 2018), *TsoiChem*© (Dekhane & Tsoi, 2012) and many more. However, these mobile game applications are just focused on general knowledge and learning outcome of certain chemistry topics. The mobile game application available is not customised based on Malaysia matriculation Chemistry syllabus specifically on the thermochemical equation and does not build upon

characteristic of Gen Z in this 21st-century learning environment (Wan Fatimah Wan Ahmad, & Nabil Fikri Abdul Rahman, 2014; Antunes *et al*., 2012; Cahyana, Paristiowati & Fauziyah, 2018; Dekhane & Tsoi, 2012; Mulop, Yusof & Tasir, 2012).

Furthermore, lecturers often complained they are lacking resources especially preparation time, specific training, classroom setting, and financial support when they want to apply technology in teaching (Sánchez-Mena & Martí-Parreño, 2017). Therefore, the mobile game application developed could be used as teaching and learning tools in the classroom lesson.

In a conclusion, students face difficulties in writing thermochemical equations which would affect their achievement and their understanding of the subsequent topic. The remaining chemistry topic is interconnected and extended from prior knowledge of writing a thermochemical equation. Mobile enthalpy game application is proposed in this study to address the problem discussed. The student's misconceptions in writing thermochemical equations are designed into game levels so that their misconception could be addressed effectively. The student could learn how the variables in the chemistry concept interact with each other from playing a mobile game application (Zydney & Warner, 2016).

1.4 Objectives of the Study

The objectives of the study include:

a) To design and develop mobile enthalpy game application, MEGA for teaching thermochemical equations among matriculation students.
b) To estimate the content, pedagogical, and multimedia validity index of MEGA.
c) To estimate the reliability index of MEGA.
d) To analyse the effects of MEGA on students' achievement in the thermochemical equation.
e) To identify the strengths and weaknesses of MEGA.

1.4.1 Research Questions

The research questions in this study are:

a) What is the content, pedagogical, and multimedia validity index of MEGA?
b) What is the reliability index of MEGA?
c) (i) Is there any significant difference between the control group and experimental group scores in pre-test 1?

   (ii) Is there any significant difference between the control group and experimental group scores in pre-test 2?

   (iii) Is there any significant difference between the control group and experimental group scores in pre-test 3?

d) (i) Is there any significant difference between pre-test 1 and post-test 1 scores for the control group?

(ii) Is there any significant difference between pre-test 2 and post-test 2 scores for the control group?

(iii) Is there any significant difference between pre-test 3 and post-test 3 scores for the control group?

e) (i) Is there any significant difference between pre-test 1 and post-test 1 scores for the experimental group?

(ii) Is there any significant difference between pre-test 2 and post-test 2 scores for the experimental group?

(iii) Is there any significant difference between pre-test 3 and post-test 3 scores for the experimental group?

f) (i) Is there any significant difference between the control group and experimental group scores in post-test 1?

(ii) Is there any significant difference between the control group and experimental group scores in post-test 2?

(iii) Is there any significant difference between the control group and experimental group scores in post-test 3?

g) What are the strengths and weaknesses of MEGA?

1.4.2 Research Hypothesis

The following null hypotheses are formulated to address research questions (c) to (f)

a) H_{01}: There is no significant difference in the pre-test 1 scores between control and experimental groups.
b) H_{02}: There is no significant difference in the pre-test 2 scores between control and experimental groups.
c) H_{03}: There is no significant difference in the pre-test 3 scores between control and experimental groups.
d) H_{04}: There is no significant difference between pre-test 1 and post-test 1 scores for the control group.
e) H_{05}: There is no significant difference between pre-test 2 and post-test 2 scores for the control group.
f) H_{06}: There is no significant difference between pre-test 3 and post-test 3 scores for the control group.
g) H_{07}: There is no significant difference between pre-test 1 and post-test 1 scores for the experimental group.
h) H_{08}: There is no significant difference between pre-test 2 and post-test 2 scores for the experimental group.
i) H_{09}: There is no significant difference between pre-test 3 and post-test 3 scores for the experimental group.
j) H_{10}: There is no significant difference in the post-test 1 scores between the control and experimental groups.
k) H_{11}: There is no significant difference in the post-test 2 scores between the control and experimental groups.
l) H_{12}: There is no significant difference in the post-test 3 scores between the control and experimental groups.

1.5 Conceptual Framework

According to Chua (2014), the conceptual framework is used to illustrate the relationship between variables in the study. The conceptual framework in the study is shown in Figure 1.2.

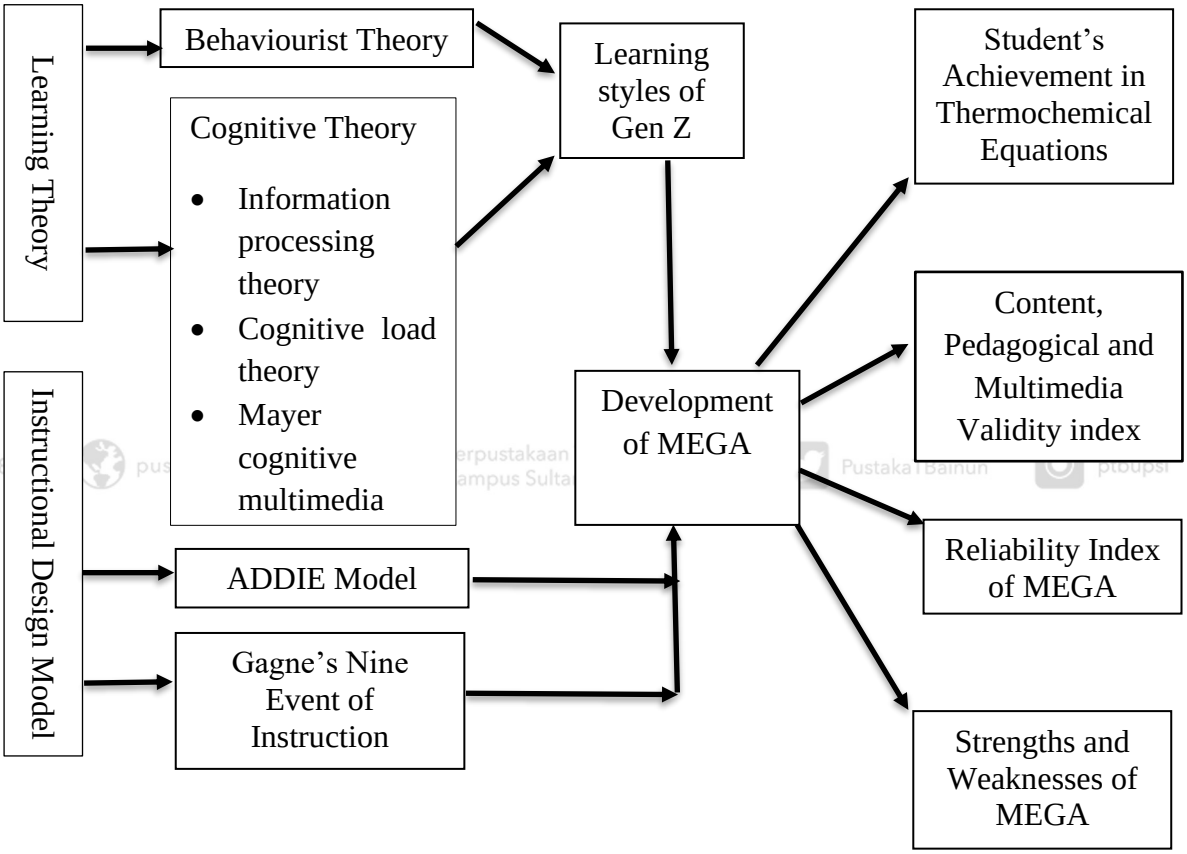

Figure 1.2. Conceptual Framework of The Study

This study involves the development of MEGA and measures its validity index in content, pedagogical, and multimedia aspects. Besides, the reliability index of MEGA is also estimated. MEGA is also used to study the effects on matriculation student's achievement in the thermochemical equation.

In the development of MEGA, two main learning theories were used; behaviourist and cognitivist theory. Behaviourist theory is chosen because student's achievement in writing thermochemical equations could be improved based on practices, guidance, hints, rewards, and punishments provided in the game application. The cognitivist theories that were applied in the development of MEGA include information processing theory, Mayer cognitive multimedia learning, and cognitive load theory. The MEGA could be used as one of the interactive resources to address student's misconceptions in thermochemical equations to improve their understanding and achievement.

The MEGA is designed based on cognitive load theory. The learning of thermochemical equations is divided into small game goals that need to be achieved by the players. Students will learn actively through playing MEGA because the multimedia elements applied in MEGA train the student to process information efficiently. Instead of learning theories, the learning styles of Gen Z were paying focus on the development of MEGA. MEGA uses a smartphone as the main platform in its operation which is very familiar to the Gen Z generation lifestyle.

The instructional design model used in this study is the ADDIE model and Gagne's nine events of instructions because it could provide systematic procedures in developing MEGA. Both models worked complementary with each other to produce a high quality digital game application which will be discussed in detail in chapter 2.

1.6 Significance of the Study

The findings of this study are important and beneficial to a few parties.

1.6.1 Matriculation Students

With the research finding of MEGA, the researcher hopes that students can improve their skills in the thermochemical equation through active participation in the game activity. MEGA optimizes Gen Z's learning styles. Students can visual formation of the stable ionic compound using puzzle pieces. Students could manipulate the answer in MEGA by using a smartphone keyboard. Therefore, MEGA is another source of reference for matriculation students instead of reference books, lecture notes, and tutorial questions.

It is hoped that by using MEGA, a student's misconception in writing thermochemical equations such as imbalance thermochemical equations, equations without phase, and mistake in writing the molecular formula of the ionic compound could be addressed.

1.6.2 Lecturers

By using MEGA, lecturers could incorporate a variety of teaching and learning inputs in class when teaching the thermochemical equation. The teaching approach is not

limited to lecture notes, tutorial questions, or reference books but using interactive teaching materials such as mobile game applications.

The development of this game application could help lecturers to deliver difficult lessons not only in the classroom but beyond the class. Guidance still can be given to students even after school time. The use of digital game-based learning such as MEGA in the classroom could create more fun, engaging, and student-centered learning environment.

A detailed lesson plan provided could give an idea to lecturers on how to manage their time effectively when using the mobile game application in the classroom. Findings of this research can help lecturers to plan digital game-based learning lesson which is suitable for Gen Z's learning styles. This finding also can be shared among lecturers to enhance the performance of students by overcoming student's weaknesses in writing a thermochemical equations.

1.6.3 Matriculation Division

Benefited from findings of this research, it is hoped that result of the Malaysia Matriculation Programmes Examination in Chemistry SK025 could be improved and eventually produces high qualification of science, technology, engineering, and Mathematics (STEM) students that can fulfill employment needs for 21st century. The MEGA is one of the strategies to leverage ICT especially mobile technology to improve the learning quality of students. The MEGA enabled Gen Z to learn according to their

own pace. This indirectly harnesses Gen Z digital skills and competencies of using mobile technology to assist their learning.

1.7 Study Limitations

The MEGA only supports Android-based operating system 7.1 and above. It works offline and involves the only a single player. The MEGA is designed to teach only thermochemical equations topic for six enthalpies process which includes enthalpy of formation, atomisation, combustion, neutralisation, hydration, and solution based on Malaysia matriculation syllabus semester 2 in Malaysia. This study only involves 72 students. This study only studies the effect of MEGA on student's achievement in the thermochemical equation by using three pre-tests and three post-tests. The strength and weaknesses of MEGA are identified by using the MEGA evaluation form.

1.8 Operational Definition

There are few terms used in this study and they were defined as:

1.8.1 The effect

The effect is a change occurred from an action or other causes. The positive effect or benefits produced when GBL application such as MEGA success produces a desired or positive impact on a result to make the learning process attractive and efficient

(Giannakas, Kambourakis, Papasalouros, & Gritzalis, 2017). On the other hand, the negative effect happens when producing negative impacts on the results. In this study, the effect is associates with the capability of MEGA as student's learning tools on their achievements in writing a thermochemical equations. The effect is measured by differences in the mean score of students' pre-tests and post-tests.

1.8.2 Game Validity

The game validity could be estimated through four criteria according to Peter, Vissers, and Heijne (1998). The four criteria include psychological validity, structural validity, process validity, and predictive validity.

According to Peter, Vissers, and Heijne (1998), the game is valid when it displays a realistic environment to its players in psychological validity. Structural validity states that there must be a coherence between the element in the game such as information, scenario, and rules with the theory and assumption applied in the game design. The process observed in the game must be coherence with the process in reality to achieve process validity. In predictive validity, the game is valid when it gives a similar outcome either players are in or outside of the game. Besides, the player's performance in the future could be estimated by using a valid game.

In this study, the game validity was checked by experts in three aspects; content, pedagogy, and multimedia. The content of MEGA was validated by experts based on

the coherency between learning outcomes of thermochemical equations topic in the Malaysian Chemistry Matriculation syllabus with a prototype of MEGA.

The pedagogical validity of MEGA was evaluated based on coherency between two learning theories, behaviourism and cognitivism theory and game system. The multimedia validity of MEGA was evaluated based on coherency between the multimedia element in MEGA with the game system. All game validities were performed by using the evaluation checklist. The data of evaluation checklists were analysed by using Cohen's Kappa coefficient.

1.8.3 Game Reliability

The game reliability refers to the consistency or stability of a measuring score in a game (Jackson, 2006). Therefore, a similar score should be obtained when measurements are made each time. In this study, the reliability of the game is measured by the consistency of student's scores in each game level. Students are given two trials in playing MEGA. The gap between the two trials is three days. The game reliability was analysed by using game score recorded in both games playing session

1.8.4 MEGA

The MEGA refers to Mobile Enthalpy Game Application. MEGA was developed using the *Unity game engine* which enables students to learn across multiple contexts through

social and content interaction using a personal electronic devices (Crompton, 2013). The game is developed in the Android application package file (apk file) created for the Android operating system. The game required installation on an Android device with operating system 7.1 and above. It is a game which exposes students with techniques to write a thermochemical equation based on different types of enthalpy reactions with the time challenge.

1.8.5 Thermochemical Equations

Every chemical reaction in chemistry is represented by its equation to explain the chemical process that takes place. The thermochemical equation is a balanced chemical equation with phases and shows the enthalpy change of reaction between products and reactants (Ling, Zaharah Aiyub, Brown, Foote, Masterton, & Hurley, 2013). Overall, there is six types of enthalpies in the Malaysia chemistry matriculation syllabus. Each enthalpy definition is presented in Table 1.2. Based on each definition, the value of enthalpy is determined by different numbers quantity of reactants or products as stated in the definition.

Table 1.2

Definition of Each Enthalpy Process (Ling et al.,2013)

Type of enthalpy	Definition
Formation	Enthalpy change when one mole of the compound is formed from the elements in their stable state under standard condition (25^oC, 1 atm)
Combustion	Heat change when one mole of a substance is completely burnt in oxygen under standard conditions (25^oC, 1 atm)

(*Continued*)

Table 1.2 (Continued)

Type of enthalpy	Definition
Atomisation	Heat absorbed when one mole of gaseous atoms is formed from the element under standard conditions (25^oC, 1 atm)
Neutralisation	The energy released within one mole of hydrogen ion of acid is completely neutralized by hydroxide ions from base to form one mole of water.
Solution	Energy absorbed or liberated when one mole of a compound is completely dissolved in a large quantity of water to form an infinitely dilute solution.
Hydration	The energy is released when one mole of gaseous ion is hydrated by water molecules.

1.8.6 Student's Achievement

Academic achievement refers to the level of knowledge and skills attained from a course. It could be evaluated through an examination conducted by the educational institution (Yüksel & Geban, 2014). Therefore, a student's academic achievement is determined from their test score or examination grade according to the standard measurement.

In this study, the student's achievement in the thermochemical equation is evaluated based on their score in subjective questions of pre and post-tests. The score in pre and post-test is converted into a percentage that representing their achievement level in writing thermochemical equations. According to the matriculation college division, the test score and its interpretation are given in Table 1.3.

Table 1.3

Test Score and Its Interpretation

Test score (%)	Grade	Point	Interpretation
80-100	A	4.00	Excellent
75-79	A-	3.67	Excellent
70-74	B+	3.33	Excellent
65-69	B	3.00	Distinction
60-64	B-	2.67	Distinction
55-59	C+	2.33	Pass
50-54	C	2.00	Pass
45-49	C-	1.67	Fail

Students are required to apply their knowledge based on the definition standard enthalpy of each chemical reaction to solve the question given in pre and post-tests. There are three aspects of student's skills in writing thermochemical equation: i) ability to write a correct molecular formula and balancing chemical equation, ii) ability to write a correct physical state of each chemical element, and iii) determine value enthalpy correctly. Each of the correct skills will be given one mark in the answer scheme.

1.9 Summary

The problems faced by matriculation students when learning thermochemical equations are misconceptions, weaknesses in the mastery of the concept, lacking interactive references especially mobile game application in learning thermochemical equations topics. Hence, the mobile game application is suggested to overcome student's learning problems in writing thermochemical equations. The MEGA is designed based on the digitalization and automation concept in Industrial Revolution 4.0. It could be used to cater learning preferences of Gen Z through its real-time feedback, reward-processing,

and scaffolding guidance to its users. The learning supported by a mobile game application could go beyond the classroom and follow the learner's own pace. Therefore, a mobile game application could serve as an ideal learning material to engage Gen Z actively into a lesson and address their misconceptions in writing thermochemical equations.