Cakrawala Pendidikan
Jurnal Ilmiah Pendidikan
Vol. 42 No. 1, February 2023, pp.64-76
https://journal.uny.ac.id/index.php/cp/issue/view/2422
DOI: https://doi.org/10.21831/cp.v42i1.35394

Embracing gen-z's learning styles with a mobile enthalpy game application (MEGA) for thermochemical equation

Sze Yee Choo[1], Hafsah Taha[2*]
[1]Kedah Matriculation College, Malaysia, Malaysia, [2]Sultan Idris Education University, Malaysia, Malaysia
*Corresponding Author: hafsah@fsmt.upsi.edu.my

ABSTRACT

Gen-Z is digital natives with unique learning styles. Gen Z is attracted to mobile technology and interactive visual learning materials. Therefore, the mobile game application seems to engage Gen Z in learning abstract chemistry topics. This paper focuses on the effectiveness of an Android game app, mobile enthalpy game application (MEGA) to facilitate students to write thermochemical equations and study its effect on their achievement in the topic. The study involved 72 Malaysian science matriculation students divided into control and treatment groups. The impact of MEGA (treatment group) versus PowerPoint slides (control group) on students' performance writing thermochemical equations was compared. Results showed significant differences in pre and post-test scores for students in MEGA and PowerPoint groups. Students in the treatment group surpassed the control group's performance in the post-test scores. To conclude, the mobile game apps (MEGA) seemed to be able to promote gen Z's achievement and interest in learning.

Keywords: mobile game application, Gen Z learning styles, thermochemistry, Android, student achievement.

Article history

Received:	*Revised:*	*Accepted:*	*Published:*
9 July 2022	*29 November 2022*	*18 January 2023*	*7 February 2023*

Citation (APA Style): Choo, S. Y. & Taha, H. (2023). Embracing gen-z's learning styles with a mobile enthalpy game application (MEGA) for thermochemical equation. *Cakrawala Pendidikan: Jurnal Ilmiah Pendidikan, 42*(1), 64-76. doi:https://doi.org/10.21831/cp.v42i1.35394

INTRODUCTION

Chemistry learning involves understanding the three dimensions of chemistry; descriptive (macro), representational (symbolic), and explanatory (sub-micro) as suggested by Johnstone (Talanquer, 2010). The representational level involves explaining chemistry concepts using symbolic language and notation such as equations, symbols, graphs, mathematical manipulation, and letters. Students struggle with understanding a symbolic representation when they need to explain the microscopic behavior of molecules using a symbolic representation that is invisible to the naked eye (Karacop & Doymus, 2013; Nyachwaya, 2012).

The Malaysian matriculation program is a foundation course offered by the Ministry of Education to students who want to pursue their studies at a tertiary level right after secondary school. Generally, there are three science matriculation programs offered. Each program differs in science subjects; however, chemistry is compulsory for all Science Matriculation Programmes. Thirteen chapters must be completed in semester two of the matriculation syllabus (Matriculation Division, 2018). Three chapters focus on physical chemistry whereas the following ten are on organic chemistry.

Before the actual research, a need analysis study was conducted to identify learning problems Malaysian matriculation students face in studying physical chemistry and their game preferences. The study involved 96 Malaysian students of the science stream Matriculation in the 2018/2019 intake using an online survey via the Google Forms questionnaire (Choo, 2021). The need analysis study revealed that 43.0% of matriculation students rated Thermochemistry as the most challenging topic to learn especially the thermochemical equation (23.7%). 64.0% of students preferred digital games, especially mobile game application to address their weaknesses in learning chemistry subtopic.

The thermochemical equation is a balanced chemical equation showing the reaction's enthalpy change between products and reactants (Ling et al., 2013). Students should be able to write thermochemical equations for the six types of enthalpies: formation, combustion, atomization, neutralization, solution, and hydration. However, students are found to have difficulties with reactants and products, coefficient errors, subscript confusion, and determination of enthalpy value when writing thermochemical equations (Naah & Sanger, 2012; Yitbarek, 2011; Sanger, 2005). Students tend to write the wrong molecular formula based on the scientific names (Baah & Anthony-Krueger, 2012) and determine the value of enthalpy change without considering the quantity of substance reacted and the phase changes that occurred (Wiji & Mulyani, 2018). Students feel challenged as they need to acquire the both conceptual and algorithmic understanding to write the thermochemical equations correctly (Sreenivasulu & Subramaniam, 2013). Hence, an alternative teaching approach is needed to assist students in writing correct thermochemical equations.

Most materials used for teaching and learning thermochemical equations were modules, worksheets, textbooks with CD-ROMs, simulations, multimedia courseware, interactive multimedia, and web-based learning tools (Kulkarni & Tambade, 2013; Liu & Chu, 2010). Due to the industrial revolution which blooms the Education 4.0 scenario, the teaching of chemistry is moving from *chalk and talk* method towards learning with machine software. Most of the academic content is delivered in digital format via mobile technology. The self-paced learning supported by mobile technology is more personalized, engaging, flexible, and effective (Bartolomé, Castañeda, & Adell, 2018). Students learn efficiently with mobile game application guidance, hints, and supportive tools.

Today learners are unique as they are digital natives, Gen Z or iGen (Othman et al., 2019; Prensky, 2001). They viewed *learning as playing*. Since digital devices are essential to Gen Z's daily life, they look forward to their application in their learning (Bajt, 2011). Studies showed that digital game-based learning (DGBL) influences student achievement. It trains them to analyze problems, reflect on their knowledge, make connections, learn abstract topics, and master problem-solving skills (Antunes et al., 2012; Cojocariu & Boghian, 2014; Crimmins & Midkiff, 2017; Erhel & Jamet, 2013; Hwang et al., 2016; Simpson & Elias, 2011; Tsai et al.,2015; Yang, 2012).

The digital game gains popularity with the evolution of information communication technology (Naik, 2014). Digital games are familiar to the younger generation in Malaysia from 10-12 (Mohamed et al., 2010; Latif, 2007). The younger generation enjoyed the entertainment elements, game challenges, animated graphics, engaging audio, immersive simulation, and the feeling of *relaxation* in digital games (Latif, 2007). Gen Z enjoys playing games to obtain a deeper understanding of a subject (Suresh, 2012). Game-based instruction seems to be more effective in improving student learning in contrast to non-game conditions (Clark, Tanner-Smith & Killingsworth, 2016). Digital games could illustrate natural phenomena and display the relationship between the causes and effects of chemistry concepts clearly (Huizenga et al., 2017). Learning experience gained from trial-and-error in a digital game could develop students' confidence in solving chemistry problems (Hanus & Fox, 2015; Lee & Hammer, 2011). Hence, educators could transform traditional classrooms into more engaging classrooms by employing digital games and the advancement of technology.

Nevertheless, some issues were raised by scholars regarding the effect of digital game-based learning (GBL) on student achievement. It is believed GBL application encourages memory of content but does not support knowledge transfer activities (Daubenfeld & Zenker, 2015). GBL application demands less student effort in understanding chemistry concepts and a full explanation of learning contents could not be demonstrated by playing the GBL application (Khan et al., 2017). Students faced concept distraction because they could not understand the concepts well by playing the GBL application (Khan et al., 2017).

Furthermore, most mobile game applications currently do not seem to address thermochemical equation topics (Antunes et al., 2012; Cahyana et al., 2018; Dekhane & Tsoi, 2012; Mulop et al., 2012, Wan Ahmad & Abdul Rahman, 2012). For example, a mobile game application, *Chairs* was developed to teach the ring flip of cyclohexane (Winter, Wentzel & Ahluwalia, 2016), and *Chirality-2* was developed to teach functional groups, isomers, and chiral carbons for undergraduate, and high school students (Jones, Spichkova & Spencer, 2018). Most game applications developed did not conform to the Malaysian matriculation Chemistry syllabus and were not built based on Gen Z's learning styles. Moreover, teachers rarely use DGBL in their teaching since using digital games as pedagogical tools is time-consuming, creating workload issues, and involves major teacher expertise in pedagogical integration (Huizenga et al., 2017; Proctor & Marks, 2013). Teachers usually encounter problems when the games' goals are inconsistent with learning objectives (Hanghøj & Brund, 2010; Kebritchi, 2010; Naik, 2014). Therefore, active learning is hard to be achieved.

According to Mayer (2005), students could learn actively by selecting, organizing, and integrating learning materials. One of the ways to achieve it is by applying multimedia in the classroom. Mayer (2019) has suggested eleven important principles in the design and development of multimedia to maximize learners' experience through a multimedia presentation.

Based on the above background, the mobile enthalpy game application (MEGA) was designed and developed for teaching thermochemical equations by integrating Mayer's multimedia learning principles and Gen Z's learning styles according to the matriculation syllabus. The effects of MEGA on student achievement in the topic were investigated. Specifically, the following research questions were formulated to address the purpose of the current study.

Research question 1: Is there any significant difference between the students in PowerPoint (control) group and the students MEGA (experiment) group in their pre-test scores?

Research question 2: Is there any significant difference between pre-test and post-test scores for students in the control group?

Research Question 3: Is there any significant difference between pre-test and post-test scores for the students in the experiment group?

Research Question 4: Is there any significant difference between the control and treatment groups in their post-test scores?

METHOD

This study applied equivalent time-series quasi-experimental design which consists of studying both control and experimental groups by alternating treatment with a post-test measure over time (Creswell, 2008). Please refer to Table 2 for further clarification of the research design.

Development of MEGA

MEGA is an abbreviation for mobile enthalpy game application. MEGA is an offline, single-player game that requires installation on an Android device with operating system 7.1 and above. The main menu for MEGA consisted of options play, information, settings, reset, and exit as given in Figure 1.

Figure 1. The Main Menu of MEGA

MEGA was designed with challenging game levels according to student preferences identified from the need analysis study. Figure 2 illustrated game instructions and reward conditions in level 1 of MEGA.

Figure 2. The Game Instruction and Reward Condition in Level 1

The game consisted of three levels: (i) *the molecule build-up challenge*, (ii) *the battle of enthalpy*, and (iii) *the ultimate challenge*. Level 1 is a puzzle game to deduce a molecular formula for the ionic compound. The difficulties of the game increased with its levels. In level 2, students are guided with systematic steps in writing thermochemical equations however in level 3, they need to apply knowledge gained in levels 1 and 2 to determine the correct thermochemical equation for enthalpy of reaction. The answer options were modified from students' misconceptions. Students must finish the primary level within the time allocated to unlock the next level. MEGA applied three main theories, behaviorist, cognitivist, and Mayer's cognitive theory of multimedia learning to match the learning styles of Gen Z. The application of these three theories in MEGA could be illustrated in Table 1.

Table 1. Application of behaviorist, cognitivist, and Mayer's cognitive theory of multimedia learning in MEGA

Theory	Feature of MEGA
Behaviourist	Each game level in MEGA has a game mission to be achieved by the students. Both rewards and punishments are used to sustain student's responses in playing MEGA
Cognitivist	The game levels are arranged systematically according to levels of difficulty. The knowledge of writing thermochemical equations is constructed based on students' prior knowledge of writing molecular formulas for ionic compounds in-game level one.
Mayer's Cognitive Theory of Multimedia Learning	MEGA incorporates sight and sound components so students can receive and process important information efficiently.

Meanwhile, Table 2 illustrates how the principle of Mayer's cognitive theory of multimedia learning is applied in the design of MEGA specifically.

Table 2. A design feature of MEGA based on the principle of Mayer's cognitive theory of multimedia learning

Principle	Feature of MEGA
Multiple representations	There was various form of representation in MEGA such as text, graphic organizer, and animation.
Coherence principle	The instruction given in MEGA is simple and organized. Students could enable or disable the background music according to their needs.
Segmenting principle	The technique of writing thermochemical equations was broken into different enthalpy processes with focus on 1 skill to acquire in each game scene.

In MEGA, the definition of the thermochemical equation for each enthalpy process applies multiple representation principle (Mayer, 2019). Most of the contents were presented in a colourful graphic organizer. Two different presentation modes of information help learners develop two different mental representations (verbal and visual models) which could be connected easily. In addition, the molecular interaction for each enthalpy process was highlighted by using animation to facilitate students' understanding of the enthalpy process microscopically and symbolically. Students need to select, differentiate, organize, and relate between the microscopic and symbolic representations of chemical reactions continuously while playing MEGA (Mayer, 2005). According to the coherence principle, learning could be optimized when extraneous material such as unneeded detail is removed (Mayer, 2019). As a result, the instruction in MEGA is kept in simple, organized, and logical sentences. A hint option is embedded into each game scene and referred to by students when necessary. The student was given the option to enable or disable the background music according to their needs. Meanwhile, segmenting principle states that multimedia presentation could be broken into manageable learner-controlled segments to accommodate their cognitive capacity (Mayer & Pilegard, 2014). The skills in writing a thermochemical equation in MEGA was divided into a few game scenes focussing on one important skill to practice each time. Students were allowed to proceed to the next skill only if they had mastered the current skill.

Gen Z preferred active learning with observation and practice which involve both *hands-on* and *minds-on* activities (Shatto, & Erwin, 2016). Each game scene was designed to last for less than one minute to cater to Gen Z's short attention span (Shatto, & Erwin, 2016; Rothman, 2014; Hallowell & Ratey, 2011). Since Gen Z was greatly attracted by the reward-processing experience, the success to unlock the next game level was rewarded when they could answer the questions correctly (Shatto, & Erwin, 2016). Gen Z is naturally visual learners so colorful graphics help students to recall prior knowledge before playing the game (Figure 3) (Aviles & Eastman, 2012; Brumberger, 2011; Othman et al., 2019).

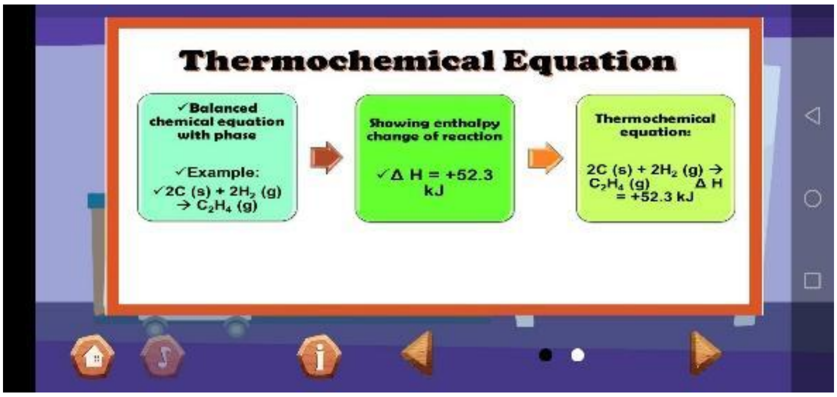


Figure 3. A Graphic In-game Information

~~S~~tudents could keep tracking their performance by comparing their recently obtained scores with the highest score achieved previously. A detailed script was created to outline the game flow in MEGA. The game content and assets were arranged into the PowerPoint storyboard. MEGA is developed by using a computer with Windows 10 and 64-bit versions. The additional specification needed is a graphic card with DX10 (shader model 4.0) capabilities and a speaker. The software used is the *unity game engine* and *Adobe Illustrator CS6* for creating the vector-type image for high resolution.

Procedure

The impact of MEGA on matriculation students' achievement in thermochemical equations was tested by using a time-series quasi-experimental study which is illustrated in Table 3.

Table 3. Time series quasi-experimental method of MEGA testing

Group	Pre-test	Independent variable	Post-test	Pre-test	Independent variable	Post-test	Pre-test	Independent variable	Post-test
Control	U_1	X_1	U_2	U_3	X_3	U_4	U_5	X_5	U_6
Experimental	U_1	X_2	U_2	U_3	X_4	U_4	U_5	X_6	U_6

Note: X_1, X_3, X_5= learning thermochemical equation utilizing PowerPoint slides, X_2, X_4, X_6 = learning thermochemical equation utilizing MEGA

The study involved a one-year science stream matriculation program for students and a 2019/2020 intake session in 15 matriculation colleges. Random sampling was applied to assign the sample as control and experimental groups. All the variables involved in the study can be illustrated in Figure 4.

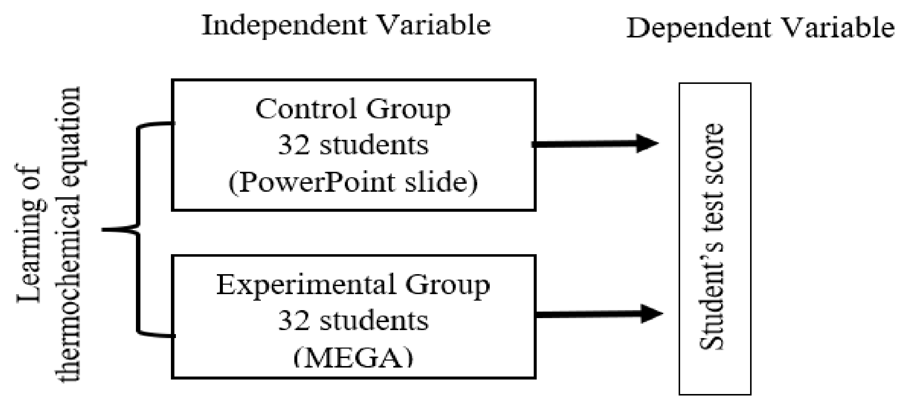


Figure 4. Variables in the Study

The study took four weeks with 50 minutes per face-to-face meeting. In the first meeting, control and experimental groups were required to answer the pre-test for 20 minutes. The pre-test asked students about combustion and formation in daily life, writing a balanced chemical equation and a molecular formula of the ionic compound. The same lecturer taught both control and experimental groups.

In the second meeting, the lecturer explained how to write a thermochemical equation to control groups. After listening to the explanation, the students filled in the blank on the PowerPoint slide handout. Students were taught how to write thermochemical equations by using PowerPoint slides. After that, they worked in pairs to solve some exercises given on PowerPoint slides. A presentation and discussion between teachers and students followed this.

On the other hand, the experimental group was required to download the executable form file of MEGA before class. Students worked in pairs, exploring the MEGA by following the flow chart in the manual guide. Students need to study the information and definition of each enthalpy in MEGA meanwhile lecturer entertained inquiries from students. Students must complete levels 1 and 2 of MEGA within 15 minutes. Similar to control groups, students in the experimental group need to solve, present and discuss the working example in pairs.

In the next meeting, students in both groups were required to answer post-test 1 and pre-test 2 and followed by learning of another two enthalpies. The time given to the students in each pre, and post-test is 20 minutes while the time allocated between each pre, and post-test was three days—the same procedure applied in the third and fourth meetings. The procedure of the study was summarised in Figure 5.

The example of a PowerPoint slide handout used for the control group and some MEGA layouts used for the experimental group is shown in Figure 6.

The instruments used were three pre-tests and three post-tests. The pre and post-test consists of three short response items that require students to write the thermochemical equation for each enthalpy process. However, students need to predict the molecular formula of a chemical compound based on the proton number of an element. An example of a post-test item is shown in Figure 7.

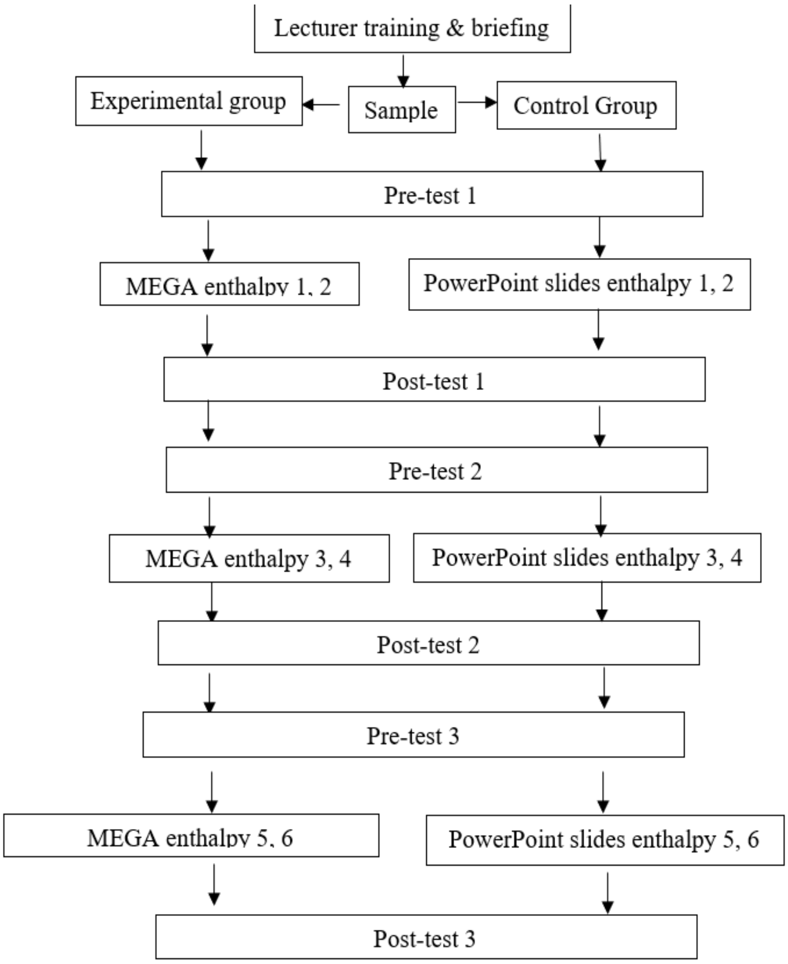


Figure 5. Procedure of Study

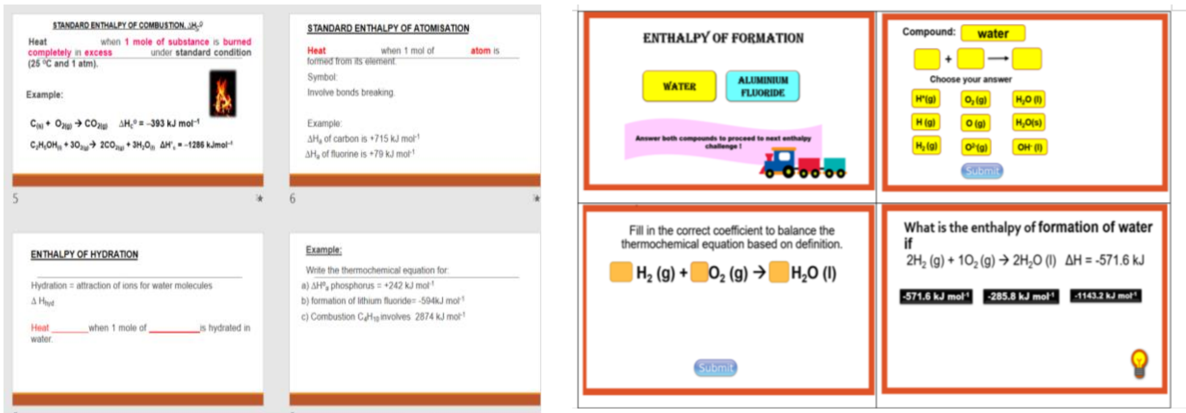


Figure 6. Example of PowerPoint Slide Handout and MEGA Layout

X is unknown solid with proton number 12. It reacts with chlorine to form a compound. Write a thermochemical equation for formation of compound X if the standard enthalpy formation of compound is -494kJ mol^{-1}. [3 marks]

Figure 7. Example of Post-Test Item

Pre-tests were used to ensure both groups were equally compatible before treatments while the post-test was used to study the effect of MEGA on student achievement. Each pre and post-test consisted of three short response questions with the same levels of difficulty and format. All pre and post-test items were validated by 2 senior lecturers to check the content, language, and learning objectives. Cohen's kappa coefficient obtained was 1.00 with total agreement achieved between the two raters (Cohen, 1960). Interrater reliability was used to estimate the reliability of the pre and post-test with a value greater, indicating indicated a strong correlation strength (White & McBurney, 2013).

FINDING AND DISCUSSION

Findings

The data collected from the study answered each of the research questions.

Research Question 1: Is there any significant difference between the students in PowerPoint (control) group and the students MEGA (experiment) group in their pre-test scores?

Table 3 shows an independent sample t-test for the pre-test scores between the control and experiment groups.

Table 3. Independent sample T-test between control and experiment groups

	Group	N	Mean	Std. Deviation	Std. Error Mean	t-value	Sig
Pre-test1	Control	36	1.14	1.222	.204	-1.011	0.316
	Experimental	36	1.44	1.340	.223		
Pre-test2	Control	36	1.22	1.355	.226	-0.184	0.855
	Experimental	36	1.28	1.210	.202		
Pre-test3	Control	36	0.81	0.749	.125	0.540	0.591
	Experimental	36	0.69	0.980	.163		

*Significant level 0.05

The pre-test 1 score of students in the PowerPoint (control) group (M = 1.14, SD = 1.22) showed no significant difference with students in the MEGA (experiment) group (M = 1.44, SD = 1.34; t (70) = -1.011, p = 0.316). The same trend was found in the pre-test 2 scores. There was no significant difference in pre-test 2 scores between the control (M = 1.22, SD = 1.36) and experimental groups (M = 1.28, SD = 1.21; t (70) = -0.184, p = 0.855). Pre-test 3 also showed no significant difference between control (M = 0.81, SD = 0.749) and experimental groups (M = 0.69, SD = 0.980; t (70) = 0.540, p = 0.591). There was no significant difference in the pre-test scores between the two groups**.** This indicated that both groups showed equivalent performances in all pre-tests. Both groups had equal prior knowledge before treatments.

Research Question 2: Is there any significant difference between pre-test and post-test scores for students in the control group?

Table 4 describes a paired sample T-test of pre-test and post-test scores for students in the control group.

Data in Table 4 showed there was a significant increase in pre-test 1 (M= 1.14, SD = 1.22) to post-test 1 score (M = 4.89, SD = 1.47, t (35) = -12.015, p = 0.000). The same trend is found in pre-test 2 (M = 1.22, SD = 1.36) to post-test 2 (M= 5.58, SD = 2.02, t (35) = -10.726, p = 0.000) and pre-test 3 (M = 0.81, SD = 1.04) to post-test 3 (M = 4.61, SD = 2.25, t (35) = -9.074, p = 0.000). Since all values of $p < 0.05$, there were significant differences between pre and post-test scores for students in the control (PowerPoint) group.

Table 4. Paired sample T-test of pre and post-test scores for the control group

	N	Mean	Std. Deviation	Std. Error Mean	t-value	Sig
Pre-test 1	36	1.14	1.22	0.204	-12.015	.000
Post-test 1	36	4.89	1.47	0.245		
Pre-test 2	36	1.22	1.36	0.226	-10.726	.000
Post-test 2	36	5.58	2.02	0.337		
Pre-test 3	36	0.81	1.04	0.173	-9.074	.000
Post-test 3	36	4.61	2.25	0.374		

*Significant level 0.05

Research Question 3: Is there any significant difference between pre-test and post-test scores for the students in the experiment group?

A paired sample T-test of pre and post-test scores for the treatment group (MEGA) was presented in Table 5.

Table 5. Paired sample T-test of pre and post-test scores for the treatment group

Experimental Group	Mean	Standard Deviation	t value	Sig
Pre-test 1	1.44	1.34	-14.559	0.000
Post-test 1	7.44	1.81		
Pre-test 2	1.28	1.21	-13.311	0.000
Post-test 2	7.28	2.36		
Pre-test 3	0.81	0.75	-18.609	0.000
Post-test 3	6.22	1.53		

*Significant level 0.05

There was an increasing trend from pre-test 1 (M = 1.44, SD = 1.34) to post-test 1 (M = 7.44, SD = 1.81, t (35) = -14.559, p = 0.00). The same trend could be seen in pre-test 2 (M= 1.28, SD = 1.21) to post-test 2 (M = 7.28, SD = 2.36, t (35) = -13.311, p = 0.00) and pre-test 3 (M = 0.81, SD = 0.75) to post-test 3 (M = 6.22, SD = 1.53, t(35) = -18.609, p = 0.00). Since all values of p are < 0.05, there were significant differences between pre-test and post-test scores for students in the MEGA group.

Research Question 4: Is there any significant difference between the control and treatment groups in their post-test scores?

Table 6 shows an independent sample t-test for post-test scores between the control and treatment groups.

Table 6. Independent sample T-test between the control and treatment groups

	Group	N	Mean	Std. Deviation	Std. Error Mean	t-value	Sig
Post-test1	Control	36	4.89	1.47	0.245	-6.573	0.000
	Experimental	36	7.44	1.81	0.302		
Post-test2	Control	36	5.58	2.02	0.337	-3.272	0.002
	Experimental	36	7.28	2.36	0.394		
Post-test3	Control	36	4.61	2.25	0.374	-3.555	0.001
	Experimental	36	6.22	1.53	0.255		

*Significant level 0.05

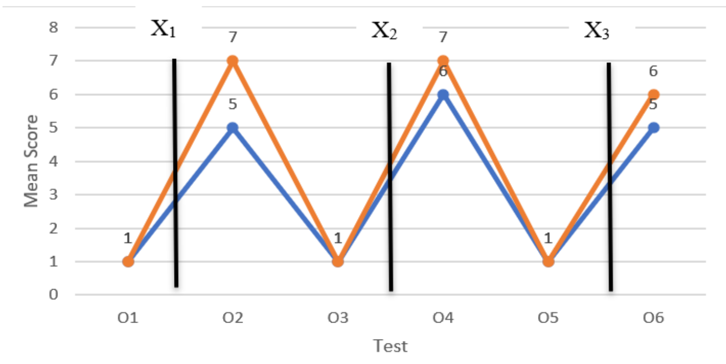
A significant difference was detected in post-test 1 scores between students in PowerPoint (control) group (M= 4.89, SD= 1.47) and the students in the MEGA (treatment) group (M = 7.44, SD = 1.81, t(70) = -6.573, p = 0.000). The post-test 2 scores of the control group (M= 5.58, SD =

2.02) varied considerably from the treatment group (M = 7.28, SD = 2.36; t (70) = -3.272, p = 0.002). A significant difference existed in pre-test 3 scores for the control group (M= 4.61, SD = 2.25) and the treatment group (M = 6.22, SD = 1.53; t (70) = -3.555, p = 0.001). All values of $p < 0.05$; hence, it could be concluded that there were significant differences in the post-test scores for the treatment group compared to the control group. The comparison was made based on the post-test scores of both groups are shown in Table 7.

Table 7. Analysis according to examination grades

Categories	Post-test 1		Post-test 2		Post-test 3	
	Control %	Experimental (%)	Control (%)	Experimental (%)	Control (%)	Experimental (%)
Fail	61.11	16.67	44.44	22.22	72.22	36.11
Pass	36.11	36.11	33.33	30.56	11.11	38.89
Distinction	2.78	19.44	22.22	16.67	8.33	19.44
Excellent	0.00	27.78	0.00	30.56	8.33	5.56

Data revealed that 61.11% of the control group failed in post-test 1, 44.44% of students failed in post-test 2, and 72.22% failed in post-test 3 respectively. Most students in the control group were in the *Fail* category for all post-tests even though they learned with the PowerPoint slides. Students needed to improve in writing thermochemical equations. On the other hand, students from the experimental group obtained a higher pass rate in the post-test than those from the control group. 16.67% of students from the experimental group failed in post-test 1, 22.22% failed in post-test 2 and 38.89% failed in post-test 3. The group that learned with MEGA exhibited average skill in writing thermochemical equations. The graph in Figure 8 showed both groups obtained similar scores in pre-tests. However, the post-test scores significantly improved for both groups after treatments. The mean post-test scores for the experimental group were higher than the control group.



Note: O_1, O_3, O_5 = Pre-test score, O_2, O_4, O_6 = Post-test score, X = introduction of learning material

Figure 8. Student's Test Score Pattern

Discussion

In the present study, results showed a significant difference in post-test scores between the control and experimental groups. The finding is consistent with previous studies (Da Silva Júnior et al., 2018; Holmes, 2012; Kavak, 2012; Sousa Lima et al., 2019) that posited game-based learning (GBL) application in the lesson improves student achievement.

Westera (2015) mentions learning by doing in a game-based learning application is not sufficient to promote deeper cognitive processing among students since learning requires both background knowledge and practical skills. However, these two important elements were available in the treatment of the experimental group. The background knowledge needed for writing thermochemical equations such as the molecular formula of the ionic compound was first recalled before students were introduced to the thermochemical equation concept. This might prepare students to mentally reconstruct their understanding based on their pre-existing knowledge.

Students could practice writing thermochemical equation skills from either the game questions in MEGA or questions given by their teacher after playing with MEGA.

After playing MEGA, the discussion on the thermochemical equation between the teacher and students could reduce concept distraction consequences from the quick content delivery of the game (Khan et al., 2017). Students could still have a full explanation from their teacher after the game.

On the other hand, even when PowerPoint presentations are used in lessons, students are passive learners as they are compelled just to copy the answers shown during lectures without understanding. Concentration and effort put in by students during lessons are limited (Singhatanadgid & Sripakagorn, 2012). PowerPoint slide presentation could be viewed as less attractive by most of the younger generation when it is less sophisticated and lacks multimedia content (Jones, 2010). Comparatively, MEGA was enriched with multimedia presentations such as graphics, animation, and audio which could sustain student interest.

A few design features in MEGA can explain the result of students' achievement in the post-test. One of the features of MEGA is segmenting. The skills in writing a thermochemical equation in MEGA were divided into small game goals which focused on one important skill to practice each time. This could reduce students' cognitive load due to their limited capacity for working memory. In contrast with the PowerPoint slide worksheets, students were presented with all materials at once, and thus it might contribute to their cognitive load.

In MEGA, simple animation of the enthalpy process could illustrate the definition of each enthalpy process compared to the static picture shown in the PowerPoint slide handout. The finding shows students who learnt with a combination of animation and narration could provide answers to different kinds of questions compared to those who learnt with only narration without animation (Mayer & Anderson, 1991). In short, graphic and words in multimedia is efficient to improve transferring knowledge among students compared to the use of words only (Mayer, 2005). Relevant facts and background music are only displayed once students need it.

Analysis of the post-test found students in the MEGA group, were able to deduce a molecular formula for the formation of ionic compounds correctly compared to the control group. This is contradicting the findings from Daubenfeld and Zenker (2015) which stated that games do not support transferring activity. Findings seemed to indicate GBL application in MEGA could facilitate students to write the thermochemical equation for the formation of chemical compounds correctly when they were provided with the proton number of elements. The puzzle game in level 1 of MEGA facilitates student understanding of writing the molecular formula of an ionic compound through visualization (Damanhuri et al., 2019).

Nevertheless, students from both groups were weak in determining the phase of the ionic compound. Students were unsure and left the question for the phase of the ionic compound in the equation unanswered. This might be due to their lack of understanding and misconceptions about the thermodynamic aspect and properties of ionic compounds (Nursa'adah et al., 2017; Kibirige et al., 2014). Results showed both groups were unable to determine reactants, products, and phase change in enthalpy of hydration and enthalpy of solution. The equation for enthalpy of the solution consists of a neutral atom rather than its respective ion. This finding is aligned with the finding from Naah and Sanger (2012). Students could not relate both enthalpies of hydration and enthalpy of a solution with the lattice energy of an ionic compound which involved a gaseous ion rather than a neutral atom (Ryan, 2000).

Overall, both groups acquired better skills in enthalpy value determination. The treatment group acquired better skills in balancing the thermochemical equation compared to the control group, despite the fact that students were still facing problems in balancing the atoms and ion charges in a chemical equation. This is consistent with results reported by Taha et al (2014) and Naah & Sanger (2012).

CONCLUSION

MEGA could improve students' achievement in thermochemical equations compared to PowerPoint slide presentations. Multiple representations provided in MEGA such as graphics, text, and animation enhanced students' learning of thermochemical equations. MEGA could assist students in deducing molecular formulas for ionic compounds through the visualization of the graphic. From the study, the noticeable changes in the experimental group included students could write the molecular formula of an ionic compound and balancing the chemical equation correctly. Learning with multiple sources primarily technological applications such as MEGA could improve students' ability to interpret the information and create their understanding of the learning material. Hence, MEGA seemed to be a very effective learning material to facilitate Gen-Z in understanding thermochemical equations.

ACKNOWLEDGMENTS

This study was supported by the Ministry of Education, Malaysia under Hadiah Latihan Persekutuan (HLP) programs.

REFERENCES

Baker-Henningham, H., & Boo, F. L. (2010). Early childhood stimulation interventions in developing countries: A comprehensive literature review. *Inter-American Development Bank and IZA*, 71.

Barreto, F. B., Sánchez de Miguel, M., Ibarluzea, J., Andiarena, A., & Arranz, E. (2017). Family context and cognitive development in early childhood: A longitudinal study. *Intelligence*, *65*, 11–22. https://doi.org/10.1016/j.intell.2017.09.006

Black, M. M., Walker, S. P., Fernald, L. C. H., Andersen, C. T., DiGirolamo, A. M., Lu, C., McCoy, D. C., Fink, G., Shawar, Y. R., Shiffman, J., Devercelli, A. E., Wodon, Q. T., Vargas-Barón, E., & Grantham-McGregor, S. (2017). Early childhood development coming of age: Science through the life course. *The Lancet; London*, *389*(10064), 77–90. http://dx.doi.org/10.1016/S0140-6736(16)31389-7

Brooks, J. B. (2011). *The process of parenting. Rahmat Fajar translation*. Pustaka Pelajar.

Caçola, P. M., Gabbard, C., Montebelo, M. I., & Santos, D. C. (2015). Further development and validation of the affordances in the home environment for motor development–infant scale (AHEMD-IS). *Physical Therapy*, *95*(6), 901–923.

Chen, W., Tanaka, E., Watanabe, K., Tomisaki, E., Watanabe, T., Wu, B., & Anme, T. (2016). The influence of the home-rearing environment on children's behavioral problems 3 years later. *Psychiatry Research*, *244*, 185–193. https://doi.org/10.1016/j.psychres.2016.07.043

Dauch, C., Imwalle, M., Ocasio, B., & Metz, A. E. (2018). The influence of the number of toys in the environment on toddlers' play. *Infant Behavior and Development*, *50*, 78–87. https://doi.org/10.1016/j.infbeh.2017.11.005

Grantham-McGregor, S., Cheung, Y. B., Cueto, S., Glewwe, P., Richter, L., & Strupp, B. (2007). Developmental potential in the first 5 years for children in developing countries. *The Lancet*, *369*(9555), 60–70. https://doi.org/10.1016/S0140-6736(07)60032-4

Iltus, S. (2007). Significance of home environments as proxy indicators for early childhood care and education. *Paper Commissioned for the EFA Global Monitoring Report*.

Iswarati. (2010). Pengetahuan keluarga dalam pengasuhan dan tumbuh kembang anak. *Gizi Indonesia Journal of The Indonesian Nutrition Association*, *33*(1), 67–73.

Jeon, H.-J., Peterson, C. A., & DeCoster, J. (2013). Parent–child interaction, task-oriented regulation, and cognitive development in toddlers facing developmental risks. *Journal of Applied Developmental Psychology*, *34*(6), 257–267. https://doi.org/10.1016/j.appdev.2013.08.002

Khadijah. (2016). *Early childhood cognitive development*. Perdana Publishing.

Kwaśniewska, J. M., Gralewski, J., Witkowska, E. M., Kostrzewska, M., & Lebuda, I. (2018). Mothers' personality traits and the climate for creativity they build with their children. *Thinking Skills and Creativity*, *27*, 13–24. https://doi.org/10.1016/j.tsc.2017.11.002

Lestari, S. (2014). *Family psychology: Value planting and handling family conflict* (Three Ed). Kencana Prenamedia Group.

Ministry of Education. (2007). *Learning guidelines for cognitive development field*. Ministry of

Education.

Pereira, K. R. G., Saccani, R., Valentini, N. C., Pereira, K. R. G., Saccani, R., & Valentini, N. C. (2016). Cognition and environment are predictors of infants' motor development over time. *Fisioterapia e Pesquisa*, *23*(1), 59–67. https://doi.org/10.1590/1809-2950/14685223012016

Putri, V. D. (2012). Childhood practices in family farmers participant of family planners "Melati" 3 in Nguken village support district Bojonegoro. *Indonesian Journal of Early Childhood Education Studies*, *1*(2). https://doi.org/10.15294/ijeces.v1i2.9211

Ronfani, L., Vecchi Brumatti, L., Mariuz, M., Tognin, V., Bin, M., Ferluga, V., Knowles, A., Montico, M., & Barbone, F. (2015). The complex interaction between home environment, socioeconomic status, maternal IQ and early child neurocognitive development: A multivariate analysis of data collected in a Newborn Cohort study. *PLoS ONE*, *10*(5). https://doi.org/10.1371/journal.pone.0127052

Suardi, Patta, B., Anshari, & Sulaiman, S. (2019). The development of a home cognitive stimulation package for 2–3-year-old children. *The New Educational Review*, *55*(1), 208–219. https://doi.org/10.15804/tner.2019.55.1.17

Suardi, S. (2017). Development of potential local-based educative book; A child stimulation guide at home. *International Conference on Education, Science, Art and Technology*, *1*(1), 194–199.

Syamsuddin, & Muhiddin. (2011). *Language educational research methodology*. PT. Remaja Rosdakarya.

Wang, P.-J., Hwang, A.-W., Liao, H.-F., Chen, P.-C., & Hsieh, W.-S. (2011). The stability of mastery motivation and its relationship with home environment in infants and toddlers. *Infant Behavior and Development*, *34*(3), 434–442. https://doi.org/10.1016/j.infbeh.2011.04.005

World Bank. (2013). *Early childhood education and development in poor villages of Indonesia: Strong Foundation, Later Success*. World Bank