JPII 12 (2) (2023) 319-328

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

ENHANCE THE UNDERSTANDING OF PERIODIC TABLE OF ELEMENT USING CROSSWORD PUZZLES AMONG FORM 4 STUDENTS

N. F. A. Rahayu[1], N. H. Ibrahim*[2], J. Surif[3]

[1,2,3]School of Education, Faculty of Social Sciences and Humanities,
Universiti Teknologi Malaysia, Malaysia

DOI: 10.15294/jpii.v12i2.41458

Accepted: December 28th, 2022. Approved: June 29th, 2023. Published: June 30th, 2023

ABSTRACT

In this study, the researcher aimed to identify students' level of understanding of the Periodic Table of Elements before and after using the crossword puzzles called Chem-PTE crossword puzzles. The quantitative approach was used as the methodology of this research and a pre-experimental base was applied to one group as the research design. 25 students were purposely selected as the respondents. The study started with a pre-test, followed by the implementation of Chem-PTE crossword puzzles for 3 lessons and subsequently ended with a post-test. Then, students' achievement scores in both, pre-test and post-tests, were analysed with descriptive analysis and paired samples t-test by using SPSS software version 24.0. The analyses were conducted to obtain the mean values for both the pre-test and post-test and next to test whether there was a statistically significant difference before (pre-test) and after (post-test) using the Chem-PTE crossword puzzles. Furthermore, this research also examined students' perspectives on the effectiveness of Chem-PTE crossword puzzles by using questionnaires. Overall, the findings showed that the use of Chem-PTE crossword puzzles had improved students' level of understanding as there was an increase in students' achievement scores in the post-test compared with students' achievement scores in the pre-test. Subsequently, the paired sample t-test analysis also revealed statistically significant differences before (pre-test) and after (post-test) the use of Chem-PTE crossword puzzles. Lastly, almost all of the students provided positive feedback on the effectiveness of the Chem-PTE crossword puzzles in enhancing students' understanding of the topic Periodic Table of Elements.

Keywords: crossword puzzles; educational games; periodic table of elements

INTRODUCTION

Chemistry education consists of three major components that include knowledge, scientific skills and scientific attitudes which the Ministry of Education (MOE) of Malaysia has emphasized in the written curriculum. But unfortunately, nowadays trends show that most students do not show much interest in enrolling in the science stream as they have a belief that any subject that has a connection with science must be a difficult subject (Phang et al., 2014; Boon et al., 2017). Based on Bradley & Moodie (2017), most students are not involved in conducting experiments since chemistry learning in schools is mostly teacher-centred and students are more likely to see the teacher's demonstration of the experiments, rather than conducting their own scientific investigations (Rasani, 2017).

Furthermore, the content of chemistry is usually seen as abstract and irrelevant because students are less interested in chemistry education as they are not being prompted to relate the chemistry knowledge to everyday life skills (Niaz & Luiggi, 2014; Franco-Mariscal et al., 2016a). Other than that, students are not exposed to chemistry that is related to the application of concepts, laws, and formulas, for example, chemistry

***Correspondence Address**
E-mail: p-norhaniza@utm.my

problems in which students need to calculate the concentration of acid and base (Ryan, 2015). These problem-solving and analytical skills should be implemented among the students especially when have been taking science since their first year of secondary school (Childs et al., 2015; Singh & Yaduvanshi, 2015). Besides, problems related to chemical context are diverse, so students need to think to solve the problems (Apriwanda & Hanri, 2022).

Subsequently, the researcher aimed to focus on the topic of the Periodic Table of Elements as based on past studies there have shown that many students have misconceptions and learning problems regarding this topic. Periodic Table of Elements is one of the topics in Form 4 Chemistry subject and the theme for the topic revolve around us.

In the topic of the Periodic Table of Elements, students need to study several groups of elements that are contained in the periodic table such as Group 18 elements, Group 1 elements, Group 17 elements, elements in Period 3 and transition elements. But, in the syllabus of Form 4 Chemistry, the students only need to learn about the Group 18 elements with uses, Group 1 elements, and Group 17 elements and focus on the periodic variations across period 3. For the transition elements, they must study the properties of a few transition elements such as those with various oxidation numbers, form coloured ions and compounds and have catalyst properties. Students only go in-depth in their Chemistry when they further at the university level such as naming the elements that have been in the transition elements and the chemical reactions involved in the elements.

According to Niaz and Luiggi (2014), the elements in the periodic table were found and arranged based on the pioneering work of Russian chemist, Dmitri Mendeleev and others from 1869 to 1889. Next, Thomson in 1897, followed by Rutherford in 1911, Bohr in 1913 and Henry Moseley in 1913 were the main contributors and founders of modern atomic theory. The current nomenclature of new elements found has been suggested and approved by the International Union of Pure and Applied Chemistry (IUPAC) and arranged based on their chemical properties. In the periodic table of elements, there are also physical properties for each element such as melting points and boiling points, heat of fusion, vaporization, energy of atomization and other properties which show periodic variations.

The concept of the Periodic Table of Elements is one of the basic concepts for students to understand and master apart from other chemistry concepts such as the mole concept, chemical bonds, chemical equations, and chemical changes involved in each chemical process. Because these concepts are very important, the failure to master a concept will cause the students to be bored and reduce their willingness to learn the subject of chemistry (Arnolds & Logg, 2014; Bradley & Moodie, 2017). This can indirectly affect students' academic achievement, especially in Chemistry.

Previous studies have proven that understanding the Periodic Table of Elements was one of the crucial topics in studying chemistry (Larson et al., 2012; Nyachwaya, 2016; Bierenstiel & Snow, 2019). It can be seen from many researchers that many students have issues learning this topic (Markie & Childs, 2016; Wimbi et al., 2021). Thus, the periodic table of elements topics is one of the hardest topics for students to make a real-life relationship with.

The Periodic Table of Elements is one of the topics that students need to learn when studying chemistry since this topic is also considered a difficult topic to relate to real life as students need to have to remember and understand the physical and chemical properties of elements in the Periodic Table as well (Liu & Taber, 2016). Moreover, the students are also confused in writing the correct chemical symbols where they fail to write a proper symbol of ionic compounds, for example, magnesium ion, Mg 2+ and iodide ion, I 2- without any symbol of positive (+) and negative (-) respectively (Liu et al., 2018). This problem may be due to a lack of understanding when they learn about the Periodic Table of Elements especially when they process further to the topic concerning ionic and covalent bonding (Vladušić et al., 2016).

Atomic structure and the periodic table are crucial parts for students to have in chemistry learning since the atomic structure and periodic table elements are the basis of understanding chemistry (Franco-Mariscal et al., 2016b). Based on Abels (2016), the main challenge faced by students in learning the topic of atomic structure and the Periodic Table of Elements is that teachers are lacking in concrete instructional materials. Next, teachers also have other work surpluses and most students have a problem mastering basic contents and skills related to chemistry. Time constraint is also one of the problems that are usually encountered by chemistry teachers as they are also loaded with teaching many periods in school not to mention, the time-specified chemistry syllabus that they also need to fulfil.

Nyachwaya (2016) also stated that the Periodic Table of Elements is a core topic in chemistry as students need to learn, understand and memorize the elements in each group of the periodic table; before they proceed to other topics involving chemical reactions. Students should be able to cover the parts of electron valences first, next the chemical formulae and followed with balancing chemical equations. Then, the students also stated that they had trouble writing the chemical formula for the ions. Here it can be said that the teaching of the Periodic Table of Elements should be improved by first understanding the electronic configuration of atoms and ions, so students can illustrate and know how positive and negative ions are formed and thus can justify each ionic formula (Taber, 2015).

Educational games are a form of learning that requires the students to have skills such as strategizing, hypothesis testing, or problem-solving, usually by applying higher-order thinking skills rather than rote memorization or simple comprehension (Hilliard et al., 2016). Using crossword puzzles as a type of educational game for chemistry learning can be an effective teaching aid to promote active learning that is more relaxed and friendly in a classroom atmosphere (Brown et al., 2018). Next, according to Mohamad Ham et al. (2017), most students prefer learning and facilitating a process which applies game elements rather than traditional methods. Based on that, the use of crossword puzzles can improve students' interests as well as strengthen the overall brain and memory function of the students which encourages them to better understand the chemical concepts, theories, and their applications (Ntoa et al., 2011).

Furthermore, educational games through crossword puzzles may enhance vocabulary mastery as well as promote problem-solving skills among chemistry students because crossword puzzle activities can make them explore and investigate the solutions to each chemical problem given (Saran & Kumar, 2015). Other than that, the crossword puzzle is an educational game that encourages students to have creative, fun and cooperative elements to transform the learning process into something more enjoyable and less threatening (Childers, 2017). Moreover, students will be entertained while completing the crossword puzzle as this will trigger them to apply teamwork, engage with each other and increase students' inquiry skills during the teaching and learning process.

Besides that, based on Radyaguru et al. (2016) crossword puzzles also reinforce social interactions between students themselves and can be applied in any discipline as well as science education. Overall, this research not only has advantages in enhancing the student's understanding of the topic of the Periodic Table of Elements but also in any other topics such as chemical bonding, electrolytes and non-electrolytes, chemical equations and mole calculations. Without a deep understanding of the topic of the Periodic Table of Elements, students will not be able to proceed with other topics as they are related to each other (Wang & Barrow, 2013).

Thus, this study aimed to enhance students' understanding of the Periodic Table of Elements by using crossword puzzles which as mentioned by Hilliard et al. (2016) uses educational games as one of the alternatives that may attract students' interest and attention during learning process in the classroom. Therefore, this study has several objectives.

i) To identify students' understanding of the Periodic Table of Elements before and after using the crossword puzzles; ii) To explore students' perceptions of using crossword puzzles when learning about the Periodic Table of Elements.

METHODS

In this study, the quantitative research method was used by the researcher to collect and analyze data obtained from the field studies. Based on Piaw (2006), quantitative approaches are best used since it aims to study and investigate the variables in phenomena under the study. Furthermore, the quantitative research method emphasized procedures to compare groups or factors associated with individuals or groups in the form of surveys, correlation studies and experimental studies (Campbell & Stanley, 2015; Hazelkorn et al., 2015). Based on Creswell (2014), two types of variables are being studied in educational research which are the independent and dependent variables. The independent variable is the presumed cause or treatment and the dependent variable is where the effect is observed and recorded.

This study was conducted using a pre-experimental research design based on one group (O1 X O2) where the researcher aimed to study the independent variable through the use of crossword puzzles whereas the dependent variable is the student's understanding of the topic of the Periodic Table of Elements. According to Creswell (2014), most situations in educational research use experimental design because the researchers need to use intact groups where this

might occur because of the availability of participants or because of its setting that may prohibit the formation of artificial groups. Next, pre-experimental was best used as a design for this study as it allows the researcher to evaluate the differences between both pre- and post-tests after the treatment is conducted (Talib, 2015).

This research involved one group of samples which was treated with crossword puzzles labelled as the experimental or treatment group. The Chem-PTE crossword puzzles that were constructed focused only on the topic of the Periodic Table of Elements for Form 4 Chemistry. The crossword puzzles also were built based on the I'6s model by emphasizing the student-centred teaching and learning process of social constructivism theory (Farida et al., 2018). The crossword puzzles were implemented through a module that consisted of 3 sets of lesson plans that included the crossword puzzles related to the periodic table. The crossword puzzles contained 20 crossword puzzle questions. The pre-test that was being carried out aimed to investigate students' level of understanding of the Periodic Table of Elements before treatment with the crossword puzzles. Then, the post-test conducted by the researcher seek to collect data after the treatments to investigate if there was an increase in students' level of understanding of the Periodic Table of Elements. The results of pre-and post-tests were then analyzed based on the research objectives.

The extraneous variable that the other influences should be controlled included the sample selection, interaction between groups, study periods, question preparation and statistics that were used which also could affect the teaching method and achievement of students which may increase the error for this study (Case & Swanson, 1998). Therefore, several steps have been taken into consideration to control the external variables such as the selection of samples comprising one group of students who have the same level of learning understanding, experimental design, and randomization (Creswell, 2014).

The instruments used in this study were pre-and post-tests, Chem-PTE crossword puzzles with a module and questionnaires. The pre-and post-tests were used to study the students' level of understanding of the Periodic Table of Elements which comprises 10 multiple-choice and five subjective questions. Next, the Chem-PTE crossword puzzles used comprised three sets as an exercise (A, B and C) to stimulate students' memory and enhance understanding of the Periodic Table of Elements. The questionnaire also used by the researcher in this study consisted of items to study students' perceptions about the effectiveness of using the Chem-PTE crossword puzzles in enhancing their understanding of the Periodic Table of Elements.

The data obtained from the pre-and post-tests were analyzed by using parametric statistic paired sample t-tests to compare the mean differences that respondents have achieved. Furthermore, paired sample t-test was used to observe any significant differences or vice versa from both, pre-and post-tests. Frequency and percentage were used in analyzing each item for the objective and subjective items.

The data obtained from the questionnaire were analysed by using descriptive statistics for close-ended questions meanwhile the open-ended questions were analysed by using the coding method. All the data obtained were analysed by using the software of Statistical Package for the Social Sciences 24.0 (SPSS 24.0) where this software provided statistical analysis to find the descriptive data such as scores, median, mean, standard deviation, percentage and frequency.

RESULTS AND DISCUSSION

Students' understanding was identified based on the achievement of the students' overall marks in the pre-test and post-test. Students' achievement also was analysed by comparing the pre-test and post-test scores. Then, the descriptive and parametric analysis (t-test) were used in the discussion of this sub-topic. Table 1 showed a dependent (paired) samples t-test was performed to test the hypotheses that the students' results for the pre-test with (mean, M = 32.04 and standard SD = 8.576) and post-test with (mean, M = 76.60 and standard deviation, SD = 10.996) were equal (alpha level, $\alpha = .05$).

Table 1. Paired Samples Statistics for Pre-test and Post-test

Paired Samples Statistics					
		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Pre-test	32.0400	25	8.57555	1.71511
	Post-test	76.6000	25	10.99621	2.19924

Table 2 shows the analysis results for the dependent (paired) samples t-test, where the result for the paired difference pre-test – post-test $t(24) = -16.082$, $p = .000$. The p-value of the test was .000, which was less than the level of significance 0.05 ($p < 0.05$), therefore the null hypothesis was rejected. Thus, there was a statistically significant difference in students' achievement scores before (pre-test) and after (post-test) using the Chem-PTE crossword puzzles.

Table 2. Paired Samples Test for Pre-test and Post-test

Paired Samples Test								
	Paired Differences							
	Mean Diff.	Std Dev.	Std Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pre-test – Post-test	-44.560	13.853	2.771	-50.279	-38.842	-16.082	24	.000

Overall, the results showed there were significant differences in the student's level of understanding of the Periodic Table of Elements before and after using the Chem-PTE crossword puzzles. The level of understanding is measured based on student's scores in the pre and post-test. This has been proven by the improvement in students' scores in the post-test compared with the pre-test. From the pre-test analysis, the students have problems calculating the number of electrons for an atom or ion. Most of them answered the wrong answer, but from the post-test analysis, there was an improvement among students as they were able to calculate the correct number of electrons and differentiate between the number of electrons and proton numbers as well as the position of proton numbers and nucleon numbers. Thus, this finding was aligned with the previous study by Yuriev et al. (2016), that crossword puzzles improved students' ability to solve the problems given and had positive impacts on students' understanding.

Furthermore, based on the pre-test analysis, students had problems writing periodic patterns for elements across the periods and down the groups. In the subjective item, the researcher asked students to compare the electronegativity pattern for element Z (caesium) with sodium atom with an explanation. Most of the students wrote that element Z has higher electronegativity compared with sodium atoms. But, the researcher found that the majority were able to answer the questions correctly with proper scientific explanations after being exposed to the crossword puzzles. The increase in students' understanding after using the crossword puzzles was supported by Kirna (2013) who claimed that students were more familiar with the topic after being given crossword puzzle exercises in the classroom as they were allowed to discuss with each other.

In the Periodic Table of Elements, the chemistry concepts in identifying the proton number were very important as it would be the extension of the understanding which allowed students to have a better grasp of writing the electron arrangement (Wang & Barrow, 2013; Noel, 2015). The researcher found that students made a mistake in writing the electron arrangement of an atom for a subjective item. Most of them wrote with answer 2.8.8.8.8.8.8.4 in the pre-test, meanwhile, in the post-test, students were able to solve the questions with the correct answers. According to Bayir (2014), this topic was also important for students to identify and students were able to write the electron arrangement well because indirectly the students would be able to identify the group and period of an element in the periodic table. From the findings, the researcher concluded that the implementation of Chem-PTE crossword puzzles had improved students' understanding based on the comparison between their answers in the pre-test and post-test.In conclusion, the researcher could summarize that the use of Chem-PTE crossword puzzles had increased students' understanding of the topic of the Periodic Table of Elements.

A set of questionnaires was given to the students after the implementation of the Chem-PTE crossword puzzles. The questionnaires were comprised of seven constructs demographic background, overall crossword puzzles evaluation, students' knowledge, skills, attitudes, the format of the crossword puzzles and students' reviews. Total number of respondents who answered the questionnaires was (N=25) students. The Chem-PTE crossword puzzles were comprised of three

sets of activities (A, B and C) where Activity A for the subtopic Periodic Table of Elements and Group 18 Elements. Then, Activity B for subtopic Group 1 Element and Group 17 Elements meanwhile Activity C for subtopic Elements in a Period and Transition Elements. Table 3 showed the percentage and mean for the overall crossword puzzles evaluation

Table 3. Overall Crossword Puzzles Perspective by the Students

	Likert Scale			
	Very Effective	**Effective**	**Less Effective**	**Not Effective**
Percentage (%)	28	64	8	0
Mean	1.80			

Based on Table 3 the perspective of the students, it could be concluded that most of the students liked and enjoyed the Chem-PTE crossword puzzles as more than 50% of the students stated that these crossword puzzles were effective. While the construct of students' knowledge, skills, attitudes and format of the crossword puzzles used, the items were evaluated based on a four-point Likert scale (SD = Strongly Disagree, D = Disagree, A= Agree and SA = Strongly Agree). Table 4 showed the percentage and mean for the construct of students' knowledge, skills, attitudes and format of the crossword puzzles construct respectively

Table 4. Crossword Puzzles Evaluation in Percentage and Mean

	Item	**Mean**	**Percentages (%)**			
			SD	**D**	**A**	**SA**
	Knowledge Construct					
1	These crossword puzzles helped to improve my understanding of this topic.	3.24	0	0	76	24
2	The questions in the crossword puzzles were sufficient to cover all the lessons.	2.96	0	16	72	12
3	Crossword puzzles can be used as a useful tool to learn about the periodic Table of Elements.	3.24	0	4	68	28
4	Crossword puzzles help me to memorize and understand the terms found in the Periodic Table of Elements.	3.32	0	0	68	32
5	These crossword puzzles enabled me to review my errors in this topic.	3.32	0	4	60	36
	Skills Construct					
6	Do crossword puzzles improve team spirit when played in groups?	3.56	0	4	36	60
7	Are crossword puzzles brain-teasing games that stimulate creative and critical thinking?	3.44	0	16	56	44
8	Doing the crossword puzzles helped me to solve any problems that we were not able to complete in class.	3.20	0	4	72	24
	Attitudes Construct					
9	Did you like and enjoy the crossword puzzles?	3.36	0	4	56	40
10	Are crossword puzzles a time-consuming exercise?	3.04	0	28	40	32
11	These crossword puzzles made the chemistry learning more interesting.	3.20	0	4	72	24
12	Should there be a huge collection of such puzzles in chemistry education?	3.16	0	8	68	24
	Format Construct					
13	The format of the crossword puzzles was clear.	3.16	0	16	52	32
14	The questions of the crossword puzzles were readily understandable.	3.20	0	8	64	28
15	The keys given were moderate to find out the exact word.	3.16	0	8	68	24

Based on Table 4, it could be concluded that for the construct of knowledge, more students strongly agreed and agreed with each item whereas only several of them disagreed on certain items. Thus, these Chem-PTE crossword puzzles had positive impacts on students' perceptions in terms of their knowledge of the Periodic Table of Elements.

Next, in the construct of reviews, the items were evaluated based on students' perceptions in terms of the crossword puzzles' weaknesses and strengths and were asked to suggest one suitable activity that should be implemented in chemistry learning. Students answered in an open-ended answer, but the researcher used the coding method to analyse the data in Table 5.

Table 5. Students' Evaluation Answers on Crossword Puzzles

	Item	Percentage (%)	Mean
	Weakness		
1.	Not covering the topic in depth	20	2.48
2.	Need more time	40	
3.	Difficult questions	12	
4.	Students were confused	28	
	Strength		
5.	Easy to understand the topic	32	2.44
6.	Interested and easy to answer	24	
7.	Improve communication and team-spirit skills	12	
8.	Encouraged critical thinking	32	
	Suitability activities for chemistry learning		
9.	Online quizzes	56	2.04
10.	Presentations	28	
11.	Experiments	8	
12.	Mentor-mentee	4	
13.	Explore race	4	

On average, the students stated that the use of Chem-PTE crossword puzzles for the Periodic Table of Elements was at a satisfactory level where 16 (64%) students had chosen effective and 7 (28%) students had chosen very effectively. Then, the researcher divided into strengths and weaknesses of the Chem-PTE crossword puzzles based on the research findings. Most of the students agreed that Chem-PTE crossword puzzles enabled them to improve their understanding of the Periodic Table of Elements. Certain terms that were used in the topic such as halogen, monoatomic, and noble gases had easily understood and memorized by the students. Students also agreed on the statements that Chem-PTE crossword puzzles helped them to review their errors or alternative conceptions as well as the crossword puzzles provided specific squares that needed to be filled. By that, students would be able to know and predict the answer by counting the number of squares in the crossword puzzles. On average, 68.8% of students had received positive feedback on Chem-PTE crossword puzzles in the aspect that their understanding of the Periodic Table of Elements. These findings were aligned with previous studies by Njoroge et al. (2013) and Utami (2014) who stated that students felt crossword puzzles should be used as a revision tool for them to improve their understanding as well as prepare in more depth for the final examination.

Besides improving students' level of confidence, 54% of the students had stated that Chem-PTE crossword puzzles also improved their skills such as team-spirit skills and enabled them to solve problems (problem-solving skills) on what they did not understand during the lessons in the class. Next, 44% and 56% of students strongly agreed and agreed that crossword puzzles could be considered as a brain teasing game and stimulated critical thinking which was supported by Saran & Kumar (2015) as they stated that crossword puzzles had improved students' thinking skills such as lateral thinking. Students thought that this kind of educational game should be found as a huge collection in the future especially in chemistry education as 72% of the students agreed

that doing crossword puzzles made chemistry learning more interesting compared to the traditional approach that only focused on lectures and finishing the syllabus immediately. These findings were also supported by the findings in the previous studies by Orawiwatnakul (2013) who stated that crossword puzzles had great positive impacts on students' overall aspects besides improving their understanding, it also enhanced students' attitudes and motivation since it supported their learning process.

Students have highlighted that Chem-PTE crossword puzzles had several strengths in which 32% of the students wrote that Chem-PTE crossword puzzles made them easily understand the whole topic about the Periodic Table of Elements. Then, there were 32% of them stated that Chem-PTE crossword puzzles had encouraged their thinking skills while completing the questions as well as students wrote the hints given were not too direct and made them more critical in answering each of the questions. Next, 24% of the students also wrote that Chem-PTE crossword puzzles were interesting and easy to understand. This meant that students felt that doing the crossword puzzles, could be used as some extra exercises for them to have a better understanding of the topic of Periodic Table of Elements. Lastly, only 12% of the students wrote that Chem-PTE crossword puzzles had improved their skills such as communication and team-spirit skills.

The findings showed that students were more likely to complete the puzzles when given the chance to work cooperatively and collaboratively with others as they thought it was more enjoyable and useful when communicating with each other while studying. The result of studies from Silva et al. (2017) and Taber & Akpan (2016) reported that most of the students deemed crossword puzzles as a fun way to learn the material while playing a game and characterized the exercise in crossword puzzles as motivating and challenging. Also, Jaramillo et al. (2012) also reported that most of the students deemed crossword puzzles as a fun way to learn the material while playing a game and characterized the exercise in crossword puzzles as motivating and challenging. Next, Coticone (2013) also claimed that crossword puzzles allowed students to participate in the learning process by challenging them and identifying gaps in their knowledge in an interactive format, this method also indirectly eliminated any misconceptions that they had (Muniyappan & Sivakumar, 2018). According to Franco-Mariscal et al. (2015), crossword puzzles are educational games and using this method to help learn a topic, is believed to involve students' participation in class activities so that it helps students obtain a better understanding of the main concepts presented and discussed. It is in line with Bayir (2014) who also found that educational games are a suitable tool for teaching the periodic table of elements in chemistry classes.

Overall, among the weaknesses that have been highlighted, the researcher could have concluded that Chem-PTE crossword puzzles may have one main weakness that involved the hints. It was said that the hints given were not too direct and needed students needed to apply more critical thinking. This is because the hints given were not too direct, indirectly it had caused the students to spend more time answering and completing each question in the crossword puzzles. "Not too direct on the hints given" also caused the students to have some confusion in finding the right answers.

CONCLUSION

Based on the findings, the researcher could have concluded that the use of Chem-PTE crossword puzzles could help students to improve their understanding of the Periodic Table of Elements. The results of the analysis showed that the percentage of students' achievement scores in the pre-test was lower than the students' achievement scores in the post-test. The increasing number of students' achievement scores in this post-test had shown that the use of Chem-PTE crossword puzzles had a positive impact on students' understanding of the topic Periodic Table of Elements. Furthermore, the results of the t-test analysis showed that there was a statistically significant difference between before (pre-test) and after (post-test) scores using the Chem-PTE crossword puzzles. Moreover, the effectiveness of the Chem-PTE crossword puzzles also was analysed based on students' perceptions through questionnaires. From the results, the analysis of the questionnaire showed that students perceived the most positive feedback about the effectiveness of the Chem-PTE crossword puzzles. Next, students' perspectives of the overall evaluation of the Chem-PTE crossword puzzles were also positive feedback as 28% and 64% of the students had chosen Chem-PTE crossword puzzles as very effective and effective respectively in enhancing students' understanding of the Periodic Table of Elements. From the results, it could be proven that the Chem-PTE crossword puzzles had positive impacts on students' understanding, skills and attitudes in learning Chemistry, especially for the topic of the Periodic Table of Elements. The stra-

tegy used by the researcher which incorporated an educational game (crossword puzzle) and applied the elements of social constructivism theory indirectly increased students' knowledge, and skills and nurtured positive values among themselves. Students were also even more confident and had good communication and team-spirit skills. Students were also more creative and applied more critical thinking when answering the questions in the crosswords puzzles and subsequently, this study was in line with the educational aspirations to produce competitive students who were able to cope with the challenges of 21st century learning. Good teaching and learning techniques in the classroom were important to determine the effectiveness of the student's performance and their level of understanding in learning a topic that was taught.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknologi Malaysia (UTM) for their support in making this project possible. This work was supported by the university grant (Q.J130000.2453.09G35) initiated by UTM.

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