Evaluation of jigsaw puzzles in writing the chemical formula of ionic compounds among the 10th grade students

M I M Damanhuri*, L D P Kumar, M T Borhan, S S Sani and H Taha

Faculty of Science and Mathematics, Sultan Idris Education University, 35900 Tanjong Malim, Perak, Malaysia.

*Email: muhdibrahim@fsmt.upsi.edu.my

Abstract. The objective of this research is to test the effect of using jigsaw puzzles towards students’ understanding in writing the chemical formulas of ionic compounds. This quasi-experimental case study design research involves 115 science stream students from two secondary schools in Larut, Matang and Selama district. Achievement test is used to measure students’ understanding in writing the chemical formula of ionic compounds. A survey is also conducted on the experimental students’ perception on the activity using questionnaires. Descriptive and inferential statistics are used to analyse the data, with the assistance of the Statistical Package for Social Sciences (SPPS) software. The findings proved that the jigsaw puzzles are effective in assisting students to write the chemical formula of ionic compounds. Students also have a positive perception towards the usage of jigsaw puzzles in teaching and learning activity. As conclusion, this jigsaw puzzle activity should be implemented in teaching and learning to assist the students in writing the chemical formula of ionic compounds. This study implies that the elements of game should be infused during the planning of teaching and learning to ensure that learning is more heuristic.

1. Introduction
Chemistry involves describing and explaining chemical reactions using the macroscopic, submicroscopic and symbolic representation [1-3]. Symbolic representation refers to the formula of chemical compound where it contains symbol of elements and subscript numbers referring to the composition of each elements [4]. Mastering the symbolic representation is essential to understand the chemistry concepts and it is fundamental in writing the chemical equations. Students fail to explore chemistry when they face difficulties in writing chemical equation which arises from their inability to write formula of chemical compounds correctly [5]. Studies have shown that the major problem is the poor understanding of the primary knowledge in the background of the formation of ionic compounds and bonding between and among elements [6].

Although students are able to manipulate chemical formula, but they tend to accept it as a mathematical problem without understanding the concept lies behind it [7]. This problem associates with the visualization of chemical representation which involves the cognitive association of conceptual component and visual component [8]. Students could not translate and interpret the chemical representations when they fail to visualize the nature of dynamic and interactive chemical process involved, from the symbol and chemical equation [7-9]. To solve the conceptual problems aroused from the inability in operating the visuospatial representation, Wu and Shah [10] addressed the use of
visualising tool in the teaching and learning chemistry. The use of ‘eChem’, chemistry software, is well known in assisting students’ conceptual understanding in chemical representations [8]. In contrast, Rodrigues [11] found that computer assisted visualizing tools acquire the information processing skills, where students need to interpret the logical instruction before understanding the chemistry content. Hence, a suitable technological and pedagogical design is needed in visualizing the concepts involved in writing formula of compounds.

To facilitate the students’ conceptual understanding in writing the chemical formula of ionic compounds, game based activities such as ‘Rainbow Wheel’ and ‘Rainbow Matrix’, are found to be effective [12]. Further innovation on the teaching and learning strategies introduced ‘ChemOkey’, a card game to familiarize students with the ionic formulas [13]. Besides that, an interlocking building block was also found to achieve the same intention [11]. Apart of these activities, teacher’s intensive focus on the students’ ability in chemical representation revealed that students are comfortable in representing the ions with puzzle type pieces [14]. They are able to explain the graphical representation with the formation of ions. Hence, jigsaw puzzles are found to be potential in enhancing the students’ ability in visualizing the chemical formulas.

This study proposes the jigsaw puzzles as the visualizing tool in writing the chemical formula of ionic compounds. It is a vital activity to engage the innovative learners in understanding the concept involved in writing the chemical formula of ionic compounds. Generally, jigsaw puzzles do indeed improve the understanding of spatial relations from 3D illustrations, where the implicit guidance of the 3D jigsaw concept requires the user to interact with well-defined objects illustrating a chosen topic [15]. According to Ritter et al., it directs the user’s attention to correlations between objects and provides a level of motivation for learning, which is hard to achieve with other concepts.

In this study, some concepts are used as basis and guide to make the research more meaningful. Conceptual framework shown in figure 1 suggests how jigsaw puzzle activity used in teaching and learning increases students’ understanding in writing chemical formula of ionic compounds to provoke thoughtful learning.

Generally, constructivism is a theory that explains how students construct their own knowledge based on experience and their existing knowledge. Through constructivism, jigsaw puzzle activity drives the learning process towards experiential learning, in which the jigsaw puzzle activity provides an experience or awareness of the concept under study.

Jigsaw puzzle activity considers the type of stimulation received by the students, the verbal and non-verbal stimuli during the learning process of writing chemical formula of ionic compounds. Jigsaw puzzle activity provides game based learning environment for students to increase their involvement in the learning process. Once students are aware of the concept in writing chemical formula of ionic compounds, then they will interpret and reflect on the concept being studied by visualising the concept. Jigsaw puzzles help students to visualize easily the concept learned. Furthermore, it will help students to evaluate, generalize and apply or test the concept more in detail. Experiential learning environment created by the jigsaw puzzle encourages learning towards thoughtful learning.

The purpose of this study is to investigate the effect of the teaching and learning activity using jigsaw puzzles to write chemical formula of ionic compounds among the form four science students (10th grade) and to evaluate the students’ level of understanding in writing the chemical formula after the teaching and learning activity. Students’ perception towards the activity is also collected. Consequently, the following research questions were investigated in this study:

1. Is the jigsaw puzzles used as visualizing tool in writing the chemical formula of ionic compounds effective in increasing students’ understanding than conventional teaching method?
2. What are the students’ perceptions on the usage of jigsaw puzzles in the teaching and learning activity on writing the chemical formula of ionic compounds?
Figure 1. Conceptual framework on how the jigsaw puzzle in teaching and learning increases students understanding in writing chemical formula of ionic compounds

2. Method
A quasi-experimental design case study is employed to research group consisting of 27-30 students. 2 set of controlled and experimental group is selected from 2 different secondary schools in ‘Larut, Matang and Selama’ district, Perak, where the total of 115 form four students (10th grade) are involved in this study. Table 1 gives brief explanation on the number of participants in each study group.

| Study Group    | School A | School B | Total |
|----------------|----------|----------|-------|
| Control group  | 28       | 30       | 58    |
| Experimental group | 29     | 28       | 57    |
| Total          | 57       | 58       | 115   |

Achievement test on writing chemical formula of ionic compounds are used to evaluate the students’ understanding. Pre-test and post-test is executed to compare the mean score. At the end of this study, a survey is also conducted on the experimental students’ perception on the activity, using questionnaires. Descriptive statistics (involving mean score and standard deviation) and inferential statistics (involving t-test) are used to analyse the data, with the assistance of the Statistical Package for Social Sciences (SPSS) software.

In this study, the jigsaw puzzles are built to meet the particular need in the selected topic. Puzzles that represent the positive and negative ions are built and the formula of the ions is written on the puzzles. Puzzles for positive ions have loops, where the number of the loops depends on the number of the positive charges of the ions, and the puzzles for the negative ions have heads pointing out. The number of heads shows the number of negative charges of the ions. The design of the puzzles for some of the
ions is illustrated in figure 2. The loops in the jigsaw puzzle will give the students the idea of atoms lacking of electrons and the heads as the atoms having excessive electrons. In the jigsaw puzzle game, students will try to solve the puzzle to form a rectangular shape figure. When students combine the puzzles with loops and heads to solve the puzzles, they will visualize the combination of positive and negative ions to form neutral compound.

Students will be able to write the chemical formula of ionic compound based on the number of ions in the solved puzzle. Figure 3 illustrates how students will solve the jigsaw puzzles to write the chemical formula of magnesium hydroxide, as Mg(OH)₂.

Achievement test on writing the chemical formula of ionic compounds was administered to both the experimental and comparison groups as a pretest before their study of the chemical formula to ascertain their prior knowledge on the topic. This test contains 25 items and the items were validated by two chemistry lecturers and an ‘expert chemistry teacher’ to ensure that the relevant content was incorporated in the respective form four (10th grade) chemistry curricula and was covered during instruction. The content validity test is analyzed using the method proposed by Pennfield and Miller [16], which introduces the score confidence interval to improve the assessment of item content relevance. The test was administered again to both groups as a posttest after they had completed studying the topic on chemical formula of ionic compounds. Each test is completed in 45 minutes. The test was developed by the researcher and consisted of open-ended questions. The content of the test was determined from curriculum guidelines, lecture materials and chemistry textbooks, which cover the major concepts on writing the chemical formula of ionic compounds. The concepts that were investigated and the corresponding question numbers in the test are summarized in table 2.

![Figure 2. Design of the puzzles for some of the ions](image1)

![Figure 3. Solving the jigsaw puzzles to write the chemical formula of magnesium hydroxide, Mg(OH)₂.](image2)
Table 2. Concepts investigated in the achievement test on writing the chemical formula of ionic compounds

| No. | Concepts                                                                 | Question numbers                        |
|-----|--------------------------------------------------------------------------|-----------------------------------------|
| 1   | Valency of common ions                                                   | 1, 5, 9, 13, 17, 19, 24, 25             |
| 2   | Compounds involving polyatomic ions                                       | 2, 6, 10, 14, 20                        |
| 3   | Usage of roman numbers in the IUPAC naming system                        | 3, 7, 11, 15, 18, 21                    |
| 4   | Predicting the formula of new ionic compounds (compounds which are not in the syllabus) | 4, 8, 12, 16, 22, 23                  |

Self-evaluation questionnaire on students’ perception on the jigsaw puzzle activity was administered to the experimental group on completion of the intervention program. The purpose of this questionnaire was to explore students’ perception on the jigsaw puzzle activity in writing chemical formula of ionic compounds. It is adapted from ‘My Class Activities’ instrument [17] and amended to suit this study. The questionnaire consists of 32 statements to which students responded on a Likert-type scale with five options: 5 = strongly agree, 4 = agree, 3 = not sure, 2 = disagree and 1 = strongly disagree. The items in the test were validated by three chemistry education lecturers to ensure the items are relevant to the activity. Each of the items was explained to students before they responded to the questionnaire to ensure that the original intent of the items was maintained. The aspects evaluated by the questionnaire and the internal consistency reliability for each construct are summarized in table 3. Since the Cronbach’s alpha value for each construct is greater than 0.70, hence the instrument is well developed and is reliable [18].

Table 3. Aspects investigated by the self-evaluation questionnaire

| No. | Perception aspects | No of items | Item number | Cronbach’s alpha |
|-----|--------------------|-------------|-------------|------------------|
| 1.  | Visualization      | 4           | 3, 9, 16, 23| 0.703            |
| 2.  | Interest           | 7           | 1, 7, 14, 27, 28, 29, 32 | 0.844          |
| 3.  | Understanding      | 7           | 4, 10, 11, 17, 18, 25, 26 | 0.817          |
| 4.  | Fun                | 3           | 21, 24, 31  | 0.767            |
| 5.  | Confident          | 3           | 5, 12, 19   | 0.894            |
| 6.  | Collaboration      | 3           | 6, 13, 20   | 0.782            |
| 7.  | Challenge          | 5           | 2, 8, 15, 22, 30 | 0.870          |
|     | Total              | 32          |             |                  |

3. Results and discussion

This study was designed to have only two groups: learning using jigsaw puzzle (experimental group) and the conventional learning (control group). The pre-test scores were analysed to determine the equivalence and homogeneity of the two groups before the experiment was performed. T-test shows that the pre-test scores for the two research groups did not differ, t (113) = 0.337, p = 0.737. The teaching and learning sessions were conducted since the two groups were similar. The analysis of the students’ scores in pre-test and post-test are shown in table 4.

However, the post-test score revealed a significant difference between the two study groups, t (55) = 4.930, p = 0.000. The effect size of the study is 0.92, indicating that the jigsaw puzzle activity is effective in facilitating the students’ understanding on how to write chemical formulas of ionic compounds. Thus, visualization is important to understand the concepts behind the chemical representation [8]. The
findings prove the potential strength and effectiveness of a new approach in writing the chemical formula of an ionic compound [11-13]. In line with the findings of Waldrip and Prain [14], puzzle-shaped ion representation used in explaining the formation of an ionic compound and the jigsaw puzzle activity can lead the teaching and learning towards high academic achievement.

Table 4. Mean scores and standard error for the experimental group and the control group in School A and B

| Research Group     | N  | Mean Score | Pre-test | Post-test |
|--------------------|----|------------|----------|-----------|
| Experimental Group | 57 | 8.56       |          | 52.42     |
| Control Group      | 58 | 8.07       |          | 38.83     |

The next interest in this study is determining the students’ perception on the jigsaw puzzle activity. The experimental group students’ perception is investigated using questionnaires. Their perception is tested mainly on visualization, interest, understanding, fun, confident, collaboration and challenge. The results of students’ responses to the questionnaires are summarized in Table 5 and Figure 4. Students’ responses are presented in three categories: the positive category that included ‘strongly agree’ (code 5) and ‘agree’ (code 4), the neutral category that is ‘not sure’ (code 3) and the negative category that included ‘disagree’ (code 2) and ‘strongly disagree’ (code 1).

Table 5. Analysis of results for each component in the self-evaluation questionnaire

| Aspects        | Positive (%) | Neutral (%) | Negative (%) | Mean | Standard Deviation |
|----------------|--------------|-------------|--------------|------|--------------------|
| Visualization  | 91           | 0           | 9            | 4.34 | 0.54               |
| Interest       | 89           | 4           | 7            | 4.27 | 0.71               |
| Understanding  | 88           | 2           | 88           | 4.09 | 0.56               |
| Fun            | 86           | 5           | 9            | 4.30 | 0.92               |
| Confident      | 81           | 2           | 18           | 4.15 | 0.66               |
| Collaboration  | 81           | 0           | 19           | 4.18 | 0.66               |
| Challenge      | 68           | 11          | 21           | 3.75 | 0.81               |

Figure 4 shows that students generally have positive attitude towards the use of the jigsaw puzzle. All the investigated aspects are agreed by more than 60% of the students in the experimental group. Science educators believe that students’ interest can be discerned through reports of their beliefs on the level and quality of task engagement and confident in performing a task [10]. Thus, the results of the self-evaluation questionnaire that were generally very positive can be viewed as an indication that the learning environment engendered greater interest among students towards learning science which will lead to effective learning. In general, the students’ positive view supports the proposed conceptual framework on how the jigsaw puzzle used in teaching and learning increases the students’ understanding in writing the chemical formula of ionic compounds. The high percentage (91%) of students agrees on visualization shows that the jigsaw puzzle activity stimulates verbally and non-verbally during teaching and learning to visualize the combination of ions. This visualization can help them to write the chemical formula of ionic compounds with ease. This finding supports the findings of Wu, Krajcik, and Soloway [19] which shows the ability of jigsaw puzzle in visualizing the concept of chemical representations.

The second highest percentage of students agrees is on the aspect of interest. Many students (89%) claim that the jigsaw puzzle can explore their interests during the process of teaching and learning. Since the jigsaw puzzle activity is a game based activity, so it is capable in encouraging students’ interest in the learning process. This aspect has a close relationship with the fun aspect where the percentage of students agreed to this aspect is also high (86%). When students enjoy doing jigsaw puzzles, then this
activity is believed to explore their interests. Thus, jigsaw puzzle activity which is an experiential learning activity could provide an active learning environment to increase students’ interest and excitement [20]. The results of this study also support Holstermann et al. [21] and Weinberg et al. [8] researches that demonstrated the importance of learning through experience to create interest among students towards learning new concept.

Jigsaw puzzle activity is an experience that can visualize the abstract concept, which in turn give students the understanding in writing chemical formula ionic compounds. This can be seen when 88% of students agree in the aspect of understanding. As proposed in the conceptual framework, high visualization (91%) leads to high understanding (88%). Basically, the jigsaw puzzle activity which uses the constructivism approach gives students the opportunity to develop new knowledge from their visualization in writing chemical formula of ionic compounds. Thus, the innovative approach in writing the chemical formula of ionic compounds is accepted by students. The findings of this study support the findings of Rahayu et al. [22] that revealed the positive impact of new approach in teaching and learning on students’ understanding and achievement while increasing their involvement.

![Figure 4. Students’ perception on jigsaw puzzle activity in writing the chemical formula of ionic compounds](image)

Students agree that the jigsaw puzzle activity can increase their confidence (81%) and collaboration skills (81%). These aspects are achieved when students explain and discuss the concepts involved in writing chemical formula of ionic compounds, and this occurs when students evaluate, generalize and apply the concepts learned as specified in the conceptual framework. Group activities under focus in the design of teaching and learning strategies [23] succeeded in producing more skilled students. Furthermore, the percentage of students who agreed that the jigsaw puzzle activity challenges the mind and their ability is 68%. This indicates jigsaw puzzle activity, an experiential learning activity can create higher-order thinking skills, HOTS [24] among the students as envisaged. However jigsaw puzzle activity focuses less on higher-order thinking skills, rather it emphasizes students’ understanding on how to write chemical formula of ionic compounds. This is one of the factor where there is still a small percentage (33%) of students who disagree and uncertain in the aspect of challenge.

4. Conclusion
As conclusion, the teaching and learning using jigsaw puzzles in the topic of chemical formula assists the early learners in visualizing and understanding the main concept underlies in writing the chemical formula of ionic compounds thus, preventing them from memorizing and accepting blindly formulas. Exploring the chemical formula of ionic compounds will lead to thoughtful learning as proposed in the
Malaysian curriculum. In the Malaysian context, efforts to improve present and future science teachers’ attitudes towards inquiry learning as suggested by the new 2012 curriculum are of particular importance and are seen as the precursor of the higher order thinking skills (HOTS) among the students. The suggested teaching innovation is potential to create an active learning environment, where students will be more engaged and experiencing their learning as well as inspiring the HOTS. The jigsaw puzzles activity is also used to capture students’ interest and attention during the teaching and learning session. Furthermore, students’ positive perception towards the usage of jigsaw puzzles implies that this jigsaw puzzle activity should be implemented in teaching and learning to improve the students’ understanding in chemistry. In contrast, the absence of excellent level of understanding in writing chemical formula of ionic compounds among students indicates that teachers need to focus more on chemical representation for in depth learning. Pedagogical element should overcome the game element infused in the jigsaw puzzles during the teaching and learning to ensure the learning objectives are achieved. Teachers should be well comprehended on the design and usage of the jigsaw puzzles as they play the main role of facilitators in teaching and learning. Finally the insights gained from this research are expected to inculcate heuristic as well as thoughtful learning among the young chemistry learners.

References
[1] Gabel D 1998 International Handbook of Science Education, eds K T Barry and J Fraser (London: Kluwer Academic) pp 223–248.
[2] Gilbert J K and Treagust D 2009 Multiple representations in chemical education, eds D T John and K Gilbert (Netherlands: Springer) pp 1–8.
[3] Johnstone A H 1982 Sch. Sci. Rev. 64 377–379
[4] Chang R 2010 Chemistry 10th Edition (New York: McGraw Hill)
[5] Baah R and Ampiah J G 2012 Int. J. Sci. Res. Educ. 5 162–170
[6] Ali T 2012 SAGE Open 2 1-13
[7] Krajcik J 1989 Meaning of school and communities, eds M Eisenhart and J G Goets (Washington DC: 88th annual Anthropological Association)
[8] Weinberg A E, Basile C G and Albright L 2011 RMLE Online 35 1-12
[9] Ben-Zvi R, Eylon B-S and Silberstein J 1986 J. Chem. Educ. 63 64
[10] Wu H-K and Shah P 2004 Sci. Educ. 88 465–492.
[11] Rodrigues S 2007 Chem. Educ. Res. Pr. 8 1–12
[12] Wulfberg G P, Sanger M J, Melton T J and Chimeno J S 2006 J. Chem. Educ. 83 651
[13] Kavak N 2012 ChemOkey: A Game To Reinforce Nomenclature J. Chem. Educ. 89 1047–1049
[14] Waldrip B and Prain V 2012 Int. J. Sci. Math. Educ. 10 1191–1213
[15] Ritter F, Berendt B, Fischer B, Richter R and Preim B 2002 Mensch & Computer, eds M Herczeg and H Oberquelle (Hamburg, Germany: Teubner) pp. 363–372
[16] Penfield R D and Miller J M 2004 Appl. Meas. Educ. 17 359–370
[17] Pereira N, Peters S J and Gentry M 2010 J. Adv. Acad. 21 568–593
[18] Cronbach L J 1951 Psychometrika 16 297–334
[19] Wu H, Krajcik J S and Soloway E 2001 J. Res. Sci. Teach. 38 821–842
[20] Stupans I, Scutter S and Pearce K 2010 Innov. High. Educ. 35 359–366
[21] Holstermann N, Grube D and Bögeholz S 2010 Res. Sci. Educ. 40 743–757
[22] Rahayu S, Chandrasegaran A L, Treagust D F and Ibnu S 2011 Int. J. Sci. Math. Educ. 9 1439–1458
[23] Dahsah C and Kruatong T 2010 Int. J. Learn. 17 45–60
[24] de Jesus H P, Almeida P, José J T-D and Watts M 2007 Res. Educ., vol. 78 1–20

Acknowledgment
The authors recognised the sponsorship given by Ministry of Higher Education (MOHE), Malaysia and Universiti Pendidikan Sultan Idris (UPSI).