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Ball and Stick Fun Model Kit for Stem Education

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Abstract
The majority of students are expected to have strong critical thinking and problem-solving abilities in 21st-century learning. Students can form mental habits that will help them succeed in any subject due to the emphasis on logical thought processes and problem-solving. The list of science, technology, Engineering, and mathematics (STEM) subjects is quite vast and chemistry is one of them. The STEM curriculum pushes students to think critically and develop original answers. Chemistry subject is believed as a major subject in the science field, however, in Malaysia, it is also deemed as one of the most challenging subjects. Crystal and chemical bonding topic are included in the Sijil Pelajaran Malaysia (SPM), Sijil Tinggi Persekolahan Malaysia (STPM), Diploma and Degree syllabus. In chemistry, the topic of crystal structure and chemical bonding is commonly taught via slide presentations explaining the theories. Thus, this kit introduces a new teaching method where students need to produce the chemical bonding or crystal structure by using the "Ball and Stick" model. The coloured balls made from styrofoam represent atoms, while a set of sticks represent the bonds that hold them together. It is a special set of tinker kits to represent how molecules look. This kit box has been sold at a fixed price of RM19.90 and it contains 200 pieces of molecular model kit, including 70 atoms (ball), 100 bonds (stick) and 30 parts for lone pair. It comes with CD-ROM for instruction, notes and exercises hence providing a fun learning tool kit for students from secondary to university level. The kits can be dismantled and rebuilt or can be used for display or as a model for teaching specific crystallographic or structural concepts. The different coloured balls represent atoms of different elements. A survey has been conducted on a small group of diploma students and 100% of students agree that this kit is both entertaining and useful in gaining insight into the subject matter.
Keywords: Chemistry, Chemical Bonding, Crystal Structure, Kit Box, Interactive Learning

Introduction

Science, technology, engineering, and mathematics (STEM) education offers a framework for interdisciplinary study and growth. Students benefit greatly from the STEM curriculum because it helps them acquire transferable abilities, such as the ability to think critically and solve problems. inventiveness. The goal of this educational project was to provide all students with the critical thinking abilities that would enable them to solve problems creatively and, in turn, make them more marketable to employers (Schaffrath, 1983). To enhance STEM teaching, numerous institutional and departmental change initiatives have promoted the use of research-based teaching strategies (McAlpin *et al*., 2022). Practical experience has always been important in science education for helping students build a set of fundamental skills that will enable them to make a significant contribution to the growth of economies. Students' acquisition of science process skills has always been the key objective. The addition of STEM education has expanded the importance of practical work in competence building to incorporate 21st century abilities. It is envisaged that these competencies would help science students build the solid foundation necessary for STEM careers (Mpofu & Mutseekwa, 2022). These objective states that the educational system should use a teaching strategy that helps students develop their critical thinking and problem-solving abilities (Sari *et al.,* 2021). According to educational studies, teachers find it difficult to draw linkages between the STEM fields and because of this, when children learn in solitary and detached ways, they frequently lose interest in science and mathematics (Kennedy *et al.,* 2014). Therefore, 21st century learning promotes students' topic mastery while producing, assessing, and synthesising information from many fields and sources for varied cultures (Rahmawati *et al.,* 2019).

Education is a process of providing and receiving knowledge that is vital to the student's future, for such reasons it is important students to be exposed to the best education method and for chemistry class mostly provides two types of teaching which are theoretical and practical (Riyad *et al.*, 2020). Enhancing understanding of the composition, characteristics, reaction and change of matter is the goal of chemistry. Chemistry claims and explanations should be backed up by observational evidence (Koller et al., 2015). In accordance with the goals of fundamental science education, Hofstein and Naaman (2007) noted that the practical method intends to enhance students' scientific processing skills, problem-solving skills, and draw their attention and establish favourable attitudes toward scientific approaches. This study investigates how teachers and students view practical labour, particularly in relation to the kinds of practical work they prioritise while teaching chemistry to help students learn (Lewthwaite, 2014). Universities, schools, and governments invested a significant amount of money to create the necessary infrastructure, create learning materials that use multimedia, and provide students with the computers they need (Ndibalema, 2014). The description of the most significant features of chemical bonding in molecules composed of atoms from the main group is the major objective of this fun model kit. Particular focus is placed on the sometimes misunderstood distinction between the physical mechanism of covalent bond formation and its depiction with chemical bonding models. The enormous popularity of these straightforward models and the corresponding rules resulted in the model conceptions being taken as accurate representations of physical reality. It was challenging to connect heuristic models of chemical bonding with quantum chemical knowledge because of the complex quantum environment, which defies human conception (Zhao et al., 2019). The goal of this study is to conduct a survey and find out the degree to which chemistry instructors make use of the ball and stick model kit as well as the degree to which they can make good use of it. It seeks to investigate the view that practical work, especially the type of practical work for chemical bonding and crystal structure topic. With this innovation, students can buy the kit at a low price and help to improve understand these topics through interactive learning.

Methodology

This section explains briefly the details of the product and how the survey was done and evaluated.

Ball and Stick Kit

The kit consists of 70 atoms represented by the styrofoam balls, 100 bonds represented by sticks and 30 parts for lone pair represents by a different size of styrofoam balls. The styrofoam balls are made of two (2) different sizes of balls which can be used to differentiate between atoms and lone pairs and two (2) different colours to differentiate between types of atoms. The stick is made of toothpicks and provided in three (3) different colours with a total of 100 sticks. The kit comes together with a set of questions from a basic understanding of atoms, then intermediate to higher challenges questions. The questions are designed specifically to trigger critical thinking and relate the chemical bonding to the materials observed in the real world. It also completes with the user guide CD-ROM which details the tutorial on how to use it for teaching and also how to use is if the user is a learner. The complete Ball and Stick kit are shown in Figure 1.

Figure 1: Ball and Stick model kit

Product Satisfactory Survey

The complete kit was given to each respondent together with a short Likert survey of five (5) questions and 10 closed questions to gauge their perceptions. The survey was created using Google forms and the respondent are students from Diploma in Engineering who took the chemistry subject in Universiti Teknologi MARA (UiTM).

During the theory lesson, students were asked to first write down on paper the bonds and types of hybridization in a few molecules. They were asked to draw the bonding structures. After completing each theory lesson, the students are asked to develop the molecule model according to what's mentioned in the lesson and discussion with the class members. After that, they are asked to run through the sets of questions in the kit. At the end of the activity, the students are requested to fill in the survey forms.

Result and Discussion

An all-too-common historical method in chemical education involves memorizing and reciting information. This approach is inefficient in a variety of ways, and as a consequence, students end up losing interest in both the subject matter and the field that is directly related to it. The availability of resources for chemical education varies greatly around the world, with many students lacking access to expensive textbooks, molecular model kits, and even occasionally instructors (Ippoliti et al., 2022). Thus, this kit is an effort to aid students in learning to visualize chemical structures in three dimensions and the survey has shown that it is effective in giving them a clear understanding of chemistry topics, especially crystal structure and chemical bonding.

There were a total of 300 students that underwent the chemistry subject in the semester and 10% were selected as the respondent. The outcome is shown in Table 1 and Table 2.

Table 1
Respondent outcome experiencing Ball and Stick kit with closed questions.

No	Question	Yes (%)	No (%)
1	Experience using other model kits for STEM lessons?	60	40
2	The model can display chemical structure, molecular bond, and bond angle in all directions.	100	0
3	The kit is suitable for students from secondary to university level?	100	0
4	I would recommend a teacher to use this in class	100	0
5	This model kit attracts Malaysian students to love chemistry subject and the science field	100	0
6	As a learning tool to help the teacher attract the student's attention	100	0
7	The price of RM19.90 is affordable for all Malaysian	70	30
8	It promotes hands-on activity which is fun and helps in better understanding	100	0
9	It is suitable to be used for teaching tools for two topics which are chemical bonding and crystal by using the same ball and stick	100	0
10	Theory in class does not help the students to imagine the reaction of chemical bonding and forming crystal	90	10

Table 2
Respondent outcome experiencing Ball and Stick kit with Likert survey (%).

No	Question	SD	D	N	A	SA
1	The instruction and exercises are easy to understand.	3.3	3.3	6.7	13.3	73.3
2	It promotes active learning.	0	0	6.7	20	73.3
3	I have a better understanding of the topic	0	0	0	10	90
4	It helps us to visualize and able to calculate coordination number and atoms per unit cell better	0	3.3	3.3	16.7	76.7
5	I understand better than the similar topic I learned during secondary school.	0	0	0	10	90

SD: Strongly Disagree, D: Disagree, N: Neither, A: Agree, SA: Strongly Agree

From the results, 60% of the participants have experienced using a STEM educational kit. This demonstrates that an excellent sample of respondents was taken for the survey and that it successfully combined respondents who had prior experience with those who had recently been exposed to the instructional STEM kit. A comparison between the Ball and Stick kit and the one that was previously used has been carried out and reviewed in an indirect manner using this sample of respondents. All of the participants reached a consensus that the model can depict chemical structure, molecular bond, and bond angle in all directions, and that it offers a delightful learning tool package for students of all academic levels, from secondary school to university. These complements the effort that lies in the pillars of Malaysia Education 4.0, as shown by the Likert poll, which shows that participants believed this kit able to be a medium for active and engaging learning.

The participants also acknowledged that the instructions and activities were simple to comprehend and that this model kit has the potential to inspire kids in Malaysia to develop an interest in the topic of chemistry as well as the realm of science. For this study, explaining the theory then demonstrating the model then providing them with exercises for building models and answering the question from the lower level cognitive to the higher cognitive level has helped the students to comprehend the topic very well. By applying a proper structured way of teaching, the understanding of the topic can be developed gradually. It is observed that exercise and activities in developing the crystal structure using the Balls and Stick kit have involved cognitive and psychomotor activity. These two activities are a few of the factors that contribute to developing a critical thinking mindset and problem-solving skills. Indirectly, the Ball and Stick kit is contributing some percent towards this development and it contributes to an easy way for learners to understand the topic delivered. Anyhow, from the Likert survey, 4% of students disagree that the questions are easily understandable. This may be because the questions were not being applied according to their level of difficulty.

In terms of the effectiveness and its suitability use for in teaching and learning, the respondents agreed that it would give a big impact on teachers to attract students' interest in chemistry topics. Even though 30% of students did not agree that the price of RM19.90 is affordable for all Malaysian, all of the students would want to recommend the kit to their network who they know to be a teacher or a lecturer in chemistry. 30% of students that did not agree that the price is affordable might be due to factors that Malaysian students have always been subsidised by the government and they spend less money on education even for their learning tools (Ahmad *et al*., 2019).

On top of that, all respondents acknowledge that the kit promotes hands-on activity which is fun and helps in better understanding and it is suitable to be used for teaching tools for two topics which are chemical bonding and crystal by using the same ball and stick. However, 10% of them did not agree that theory in class is not helping the students to imagine the reaction of chemical bonding and forming crystals. This is well understood because theories offer a foundation for understanding how individuals learn, as well as a means to explain, characterize, analyse, and predict learning. A theory, in this sense, assists us in making better-informed judgments about the design, development, and implementation of knowledge. It can be concluded that students need both theory and hands-on to help them master the topic.

According to the Likert scale poll, more than 90% of respondents claimed that the kit helps them visualise and compute coordination numbers and atoms per unit cell better and that they understand the issue subject better today than they did in secondary school. Figure 2 depicts the example of forming a crystal for face-centred cubic (FCC) and the student can easily imagine the coordination number, atoms per unit cell and how the things work (Dori & Barak, 2001). Due to the enormous popularity of these straightforward models' conceptions, students benefit from seeing these ideas in action through practical, hands-on projects, which also help them realize that they can use their knowledge for purposes other than tests and homework (Holstermann et al., 2010).

Figure 2. The crystal structure with face centre cubic (FCC) using the Ball and Stick model

Having separate models for sigma and pi bonds makes it easy for students to picture the structure of a molecule and change their original ideas as needed.

Conclusion

The purpose of this study is to raise instructors' and students' awareness of the significance of STEM education in forming an interesting environment for chemistry subjects. As for conclusions, the participants admitted that the model can display chemical structure, molecular bond, and bond angle in all directions and provides an enjoyable learning tool kit for students from secondary to university level. Students at any level of education could benefit from having an interest in STEM fields if they use this kit. It is imperative that educators find a way to make teaching and learning more interesting for their students, particularly those majoring in STEM because the demand for students with STEM backgrounds is growing at an alarming rate. Theories offer a foundation for comprehending how people learn as well as a means of elucidating, describing, analysing, and forecasting learning. However, acquiring theoretical information is useless unless students can use it in real-world situations. As far as suggestions for future work, the researchers may create an online game or an interesting quiz to pique the public's interest in the field of chemistry and encourage them to pursue it further.

References

Schaffrath, R. E. (1983). Is "why" more important than "what"? Journal of Chemical Education, 60(9), 728. https://doi.org/10.1021/ed060p728

McAlpin, J. D., Ziker, J. P., Skvoretz, J., Couch, B. A., Earl, B., Feola, S., Lane, A. K., Mertens, K., Prevost, L. B., Shadle, S. E., Stains, M., & Lewis, J. E. (2022). Development of the Cooperative Adoption Factors Instrument to measure factors associated with instructional practice in the context of institutional change. International Journal of STEM Education, 9(1). https://doi.org/10.1186 /s40594-022-00364-w

Mpofu, V., & Mutseekwa, C. (2022). Online stem teaching of practical chemistry: Challenges and possibilities. Academic Voices, 115–127. https://doi.org/10.1016/b978-0-323-91185-6.00014-8

Sari, N. A., Mulyani, S., Hastuti, B., & Indriyanti, N. Y. (2021). Analysis of high school students' stem literacy and problem-solving skills in chemistry. Journal of Physics: Conference Series, 1842(1), 012064. https://doi.org/10.1088/1742-6596/1842/1/012064

Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. Science Education International, 25(3), 246–258.

Rahmawati, Y., Ridwan, A., Hadinugrahaningsih, T., & Soeprijanto. (2019). Developing critical and creative thinking skills through Steam Integration in chemistry learning. Journal of Physics: Conference Series, 1156, 012033. https://doi.org/10.1088/1742-6596/1156/1/012033

Hofstein, A., & Naaman, R. M. (2007). The laboratory in science education: The state of the art. Chemistry Education Research and Practice, 8 (2), 105-107.

Lewthwaite, Brian. (2014). Thinking about practical work in chemistry: Teachers' considerations of selected practices for the macroscopic experience. Chem. Educ. Res. Pract. 15. 10.1039/C3RP00122A.

Ndibalema, P. (2014). Teachers' Attitudes towards the Use of Information Communication Technology (ICT) as a Pedagogical Tool in Secondary Schools in Tanzania: The Case of Kondoa District. International Journal of Education and Research, 2(2), 1–16.

Zhao, L., Pan, S., Holzmann, N., Schwerdtfeger, P., & Frenking, G. (2019). Chemical Bonding and Bonding Models of Main-Group Compounds. Chemical Reviews, 119(14), 8781–8845. https://doi.org /10.1021/acs.chemrev.8b00722

Ippoliti, F. M., Chari, J. V., & Garg, N. K. (2022). Advancing Global Chemical Education Through Interactive Teaching Tools. Chemical Science, 13(20), 5790–5796. https://doi.org/ 10.1039 /d2sc01881k

Ahmad, N., Ismail, R., & Abdul Hakim, R. (2019). Higher education subsidy in Malaysia: The benefit incidence analysis. Journal of Islamic, Social, Economics and Development (JISED), 4(25), 72-84.

Dori, Y. J., & Barak, M. (2001). Virtual and physical molecular modeling: Fostering model perception and spatial understanding. Journal of Educational Technology & Society, 4(1), 61-74.

Holstermann, N., Grube, D., & Bogeholz, S. (2010). Hands-on activities and their influence on students' interest. Research in science education, 40(5), 743-757.