



Promoting Problem Solving Ability in Enhancing Creative Reasoning through Adaptive Digital Game-Based Learning among Chemistry Undergraduate Students

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ABSTRACT

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Effective teaching and learning can be highly contributed using technology. STEM education is proved to improve student's creative reasoning ability. Creative reasoning through adaptive digital game-based learning (ADGBL) is expected to promote problem solving ability among students. Therefore, this study is aimed to analyse problem solving ability in enhancing creative reasoning through adaptive digital game-based learning among chemistry undergraduate students. Nine first year chemistry undergraduate students selected to take part in this qualitative research. All students were given modules to complete based on the technology incorporated learning module, namely ADGBL. All of them were asked to take part in an open questions survey form upon completing the module and the data were analysed using thematic analysis. As a result, students were able to prompt their problem-solving ability from simple chemistry problems using jigsaw puzzles and complicated chemistry problems while using operating robotic structures using wireless method which involves electronic and coding technology. Students are able to solve the module challenges creatively and effectively.

1. Introduction

Current teaching and learning process can be improved effectively with the use of technology. It has been a great medium of teaching and learning in all field of learning especially in science, technology, engineering, and mathematics (STEM) education. The use of technology must be effective, relevant to the syllabus, related to current issues that happening around the world as well connected in reasoning skills in which students are using their creative reasoning ability to address

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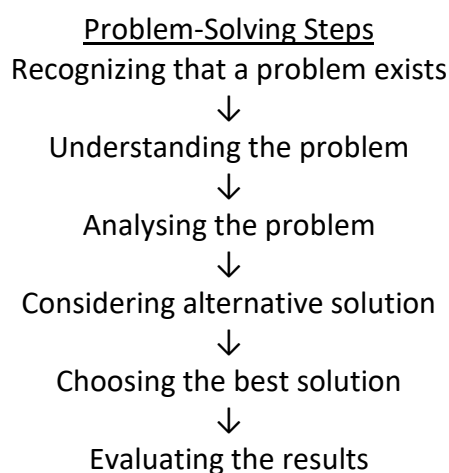
and solve a specific issue or problem. Creative reasoning skill is considered to be a priority in education [1]. Critical thinking and reasoning are defined to be making targeted and advisable judgments as to engage in the process of analysis, explanation, assessment, extrapolation, clarification, and reflection [2]. Studies have also concluded that academic accomplishment and problem-solving skills are strongly connected to critical reasoning [3]. Researchers were also found adaptive digital game-based learning (ADGBL) related studies help them to develop hands-on talents, and more understanding in STEM education [4]. Moreover, beside the effectiveness of technology in teaching and learning, students' interest and involvement are also matters in studying the effective teaching and learning session.

1.1 Teaching and Learning Chemistry through Adaptive Digital Game-Based Learning

The success of the education transformation carried out is determined by a teaching strategy adopted based on the 21st Century Learning style. The teaching and learning approach involve lectures in the classroom, using textbooks, computers, mobile phone devices and other electronic equipment. The selection of appropriate learning innovations depends on individual access to various technologies and infrastructure environments which is helpful in increasing students' interest in learning of chemistry [5-7]. Chemistry teaching and learning is always conducted in traditional way as it involves laboratory works, practical experiments as well as visual monitoring and confirmation. This is being an issue in students' performance in chemistry education. Having this in mind, ADGBL is potential factors of influence in students' interest. Students are expected to perform even better with the aid of ADGBL. ADGBL is undoubtedly an interesting medium to enhance creative reasoning skills. Moreover, the process of enhancing creative reasoning can also promote students' problem-solving ability.

1.2 Problem Solving Ability in Chemistry Education

Problem solving is the ability to find a suitable solution for a difficult problem [8,9]. It is the highest form of learning, and the problem-solving skill was an unavoidable life expertise and also defined problem solving as a method of thinking in which a student discovered the composition of the learned rules in order to solve a new problem [10-12]. Priemer *et al.*, in their research has listed different general models of problem-solving and their structures [13]. There are many structures and ways to address and overcome problems. While defining and trying to overcome the problems, it is also necessary to do it interestingly. The steps in problem solving are as below [14]:



There are several other research addressed the advantages of using ADGBL in promoting research skills including problem-solving ability [15-18]. The study reveals the efficacy of ADGBL in teaching and learning and the impact it created in academic and practical events or problems. The outcome of the study proves that ADGBL can sustain students' attention. 92% of students agreed on the attention sustainability. 90% of participants are able to connect the game with real relevant problems. 33% strongly agreed it boosts their confidence and 63% agreed with the statement. The ADGBL is able to overcome issues and 83% agreed ADGBL are rewarding and satisfying. In the context of chemistry teaching and learning, problem solving needs to be relevant to chemistry.

Chemistry students, especially at their initial learning period, might encounter many complicated issues and problems. Comparatively with other science subjects, chemistry learning involves understanding of theories as microscopic level for example chemical bonding, forces of attraction, reaction mechanism and chemical composition. Creative reasoning will assist students to stay focused in finding solutions to the problem encountered. STEM education has always encouraged students to interconnect and achieve targeted outcomes. Learning in chemistry has always been seen as challenging but with correct medium of communication and easy to reach teaching and learning aids, problem solving in chemistry education can always be an easy to achieve task.

2. Problem Background

Creative reasoning has been considered as essential to develop effective teaching and learning chemistry. Researchers proposed the application of creative reasoning as an idea of definite processes in which divergent and convergent capabilities show corresponding parts in a creative problem-solving issue [19,20]. This can be improved with the use of ADGBL. This has been agreed in previous studies which have identified lack of students' satisfaction and engagement in the problem-solving process [15]. The same study has also used ADGBL material in the study. To promote students' satisfaction and engage them in teaching and learning as well as test the effects on problem-solving ability, ADGBL model is introduced to the participants.

2.1 Research Question

Does the student's problem-solving skills enhanced with the use of ADGBL in the teaching and learning of Chemistry?

2.2 Research Objective

This study is analysing the ability of creative reasoning through ADGBL on promoting problem solving ability in chemistry teaching and learning.

3. Methodology

The authors focused on testing the problem-solving aspect with the use of ADGBL. Previous studies have addressed that valuable hypothesis for a research study must focus on independent and individual culture or learning process rather than trying to consolidate a generic effectiveness [21]. Therefore, this study will be a qualitative and focus group design. Samples of the study were targeted group of nine (n=9) chemistry undergraduate students at a local university in year 1. All the students were aged between 20 and 21 years old with mixed gender and none of them had any knowledge regarding the ADGBL used in this research.

3.1 Research Design

The aim of this research is to analyse the ability of problem solving to enhance creative reasoning ability through ADGBL module namely MYGAMBOT[®]. All the students were briefed on the MYGAMBOT[®] module. They were given one MYGAMBOT[®] Kit which contains basic structures, electronics items and working module. The module had a crossword puzzle followed by three sections. The working module also contains coding guidelines, application usage guidelines and diagrams to assist students at basic level.

The first section is building a simple MYGAMBOT[®] and operating the MYGAMBOT[®] using simple method. The instructions to build the MYGAMBOT[®] were given in indirect instructions and clues in which participants needed to solve chemistry problems to get the correct items to place at the correct location in structure. Participants will have to trigger their creativity to solve the challenge as no solution is given in the module. The second section is an advanced version of the first section where students will have to add more parts to the MYGAMBOT[®] structure to look better than basic MYGAMBOT[®] and the operating method of MYGAMBOT[®] will also be an advantaged method compared to section one. students will be required to make additional effort and follow manual instructions to successfully move the MYGAMBOT[®]. However, the students will need to solve the challenges as the guidelines will only assist them to assemble structures. The third part of the module will be using the MYGAMBOT[®] structure but the operating mode will be at higher difficulty level. The module will guide students to complete assembly, but students will need to complete the challenge with their own creativity. Moving from simple to difficult steps of operating the MYGAMBOT[®], participants will be required to be more creative and critical. The instruction will boost participants' reasoning skills because the answers from students' creativity and problem-solving skills might be wrong and might require them to think of additional or replace the idea with a new one. Figure 1 shows MYGAMBOT[®] structure.

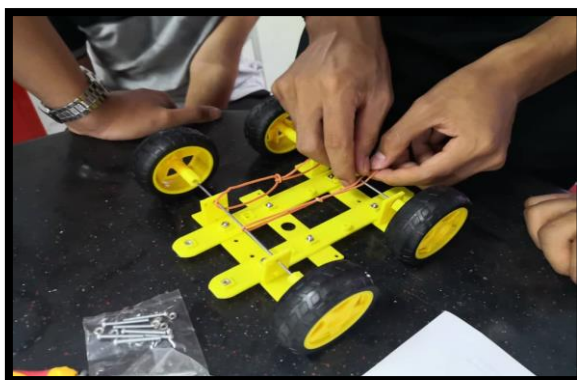


Fig. 1. Shows the second part of the MYGAMBOT[®] structure of which students need to build in order to continue to next stage of challenges

3.2 Instrument and Analysis

Upon completing the modules, students were asked to participate in an open questions survey form. The open questions survey form includes queries on effectiveness of ADGBL and its ability to trigger student's problem-solving ability in completing the modules. Problem-solving steps and ability for students to identify the steps in the challenge were also included in the survey form. The data

from the participants were analysed using thematic analysis. Students' script was coded and analysed to understand the effectiveness of creative reasoning and adaptive digital game-based learning in promoting problem solving ability.

4. Result and Discussion

The open-ended questions were included in the survey form and were analysed. The questions were on the factors that examine effectiveness of ADGBL to promote problem solving ability such as interest in learning using ADGBL model, creativity elements in teaching and learning as well as problem-solving elements in the MYGAMBOT® module.

4.1 Adaptive Digital Game-Based Learning in Promoting Creativity

To study if the MYGAMBOT® module has boosted participants creativity throughout the challenge, questions on testing creativity were included in the survey form as well. Table answers had promised students' understanding on the MYGAMBOT® module as it surely triggers creativity.

Table 1

Interview response on students' understanding on the MYGAMBOT® module for creativity

Theme	Students' statements
Creativity	"The tasks are definitely boosting our creativity" "The challenges made me to think creatively to find the solution. No direct answers, so my answers are all correct unless MYGAMBOT® not working" "I had to think differently and creatively because there's no perfect answer. The MYGAMBOT® works according to our creativity of building" "The MYGAMBOT® needs our creativity to operate for the first challenge. There's no solution given for the problem. So, creativity works and there is more than one possible answer for some challenges" "No direct answers given for the challenges, it's all about our creativity to make it work" "It is all about how you can do it yourself, creatively"

4.2 Adaptive Digital Game-Based Learning in Promoting Problem-Solving Ability

As the student does not have any knowledge in MYGAMBOT®, the problems encountered are new and challenging. They may react based on prior basic knowledge but the application to MYGAMBOT® will be totally new. As the main objective of this research is on test effects on problem-solving ability, queries on the ability of ADGBL to promote problem-solving ability were included as well. There are many elements in the MYGAMBOT® left as a challenge for participants to complete. These were the "problems" in the challenge which required participants to solve to complete the module. The challenges ranged from easy tasks to difficult tasks. Answers from students have confirmed their ability to solve all the challenges.

Table 2

Interview response on problem solving in chemistry education

Theme	Students' statements
Problem Solving	"I was able to solve the problem faster than expected" "The challenges were so difficult, no direct instructions but I able to complete them effectively" "Some challenges were easy and some are very difficult, but since the activity is interesting, I able to complete the challenges" "The module challenges were difficult as move to higher levels. It triggers us to think differently and creatively in order to solve them. I able to complete them effectively" "I loved the way the challenges were arranged from simple to complex. Even the module was not directly giving steps to complete the challenges. But when we hands-on, we able to complete effectively." "The activity is easy at start but later was very difficult, but I managed to solve all the problems" "I thought I will never complete the tasks but managed to get it done"

4.3 Problem Solving in Chemistry Education

As the need of study is focused on chemistry education, questions on problem solving in chemistry education were also included in the open questions survey form. Students described MYGAMBOT® challenges which was co-related to chemistry topics are new for them and very fun. They are motivated to do more challenges and activities with related to chemistry as long as it is connected to MYGAMBOT® teaching and learning.

Table 3

Interview Results on Problem Solving in Chemistry Education

Theme	Students' statements
Problem Solving in Chemistry Education	"I was not sure before this robotics studies were connected with chemistry studies" "The challenges were easily connected with chemistry subjects, or even more subjects" "I wish all chemistry subjects were conducted in exciting challenges like this" "Chemistry has always been a difficult subject but MYGAMBOT® has made it interesting" "I able to solve the chemistry problems with this kind of activity. It is exciting"

4.4 Problem Solving Steps in MYGAMBOT® Challenge

The steps listed in problem solving as mentioned in [14] were listed in a table in the open questions survey form and students need to answer if they can identify the problem-solving steps in the challenges and clarify in which challenge, they are able to identify the problem-solving steps in Figure 2.

Problem Solving Steps	Do you able to encounter the steps in the challenge	In which challenge, you able to identify the step?
I able to recognize the problem in the challenges		
I able to understand the need of the problem		
I able to analyse the problem		
I able to list down possible solutions for the problem		
I able to choose the best solution		
I able to evaluate the results		

Fig. 2. Problem solving steps

The feedback from the students were grouped into category of yes, no and not sure and plotted in below bar chart for better understanding. The results tabulated in Figure 3 clearly demonstrate that the students were able to understand and identify the problem-solving steps in the MYGAMBOT® challenge. They were able to recognize problems in the MYGAMBOT® challenge, understand the problem, analyse it, able to gather possible solutions, analyse the solutions and choose the best answer as well as evaluate the results.

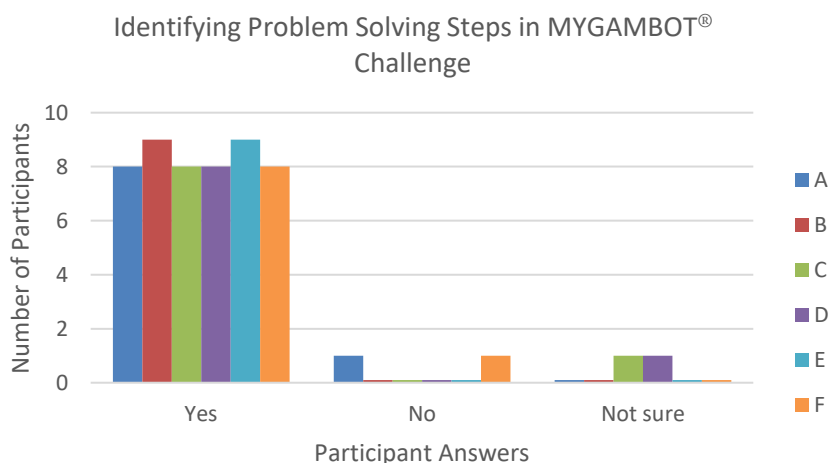


Fig. 3. Students' feedback in MYGAMBOT® challenge

- A. I able to recognize the problem in the challenges
- B. I able to understand the need of the problem
- C. I able to analyse the problem
- D. I able to list down possible solutions for the problem
- E. I able to choose the best solution
- F. I able to evaluate the results

4.5 Adaptive Digital Game-Based Learning in Promoting Interest in Learning

The students were asked about the ability of ADGBL model to promote their interest in chemistry teaching and learning process. Below, Table 4 displays the responses from students confirming that the ADGBL model has sparked their interest in learning. Students expressed their excitement, interest, and fun in learning emotions in their answers.

Table 4

Interview response on students' interest

Theme	Students' statements
Promoting interest	"It was exciting to learn through game-based learning module" "MYGAMBOT® in teaching and learning is very interesting" "Usually, we were given notes or need to learn from books, but robots in teaching and learning is something new and exciting" "Using MYGAMBOT® in teaching and learning is something very new for us. Great to learn many new things like electronics, coding and usage of phones to operate the robots" "This is very interesting and exciting"

5. Conclusion

The study clearly shows that problem solving through ADGBL can promote creative reasoning skills effectively and able to provide creative solutions. The ADGBL namely MYGAMBOT® is an interesting and exciting learning module which triggers students' interest and creativity to learn. Teachers can use MYGAMBOT® to foster students' engagement in the classroom. MYGAMBOT® is able to make classroom a better learning environment.

5.1 Future Research

Future studies can be conducted to study the ability of MYGAMBOT® model in promoting student's creativity and problem-solving abilities outside classrooms. Modules can be prepared based on laboratory works and practical works to assess students' performance and analyse the outcome.

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References

- [1] Lee, JuHee, Yoonju Lee, SaeLom Gong, Juyeon Bae, and Moonki Choi. "A meta-analysis of the effects of non-traditional teaching methods on the critical thinking abilities of nursing students." *BMC medical education* 16 (2016): 1-9. <https://doi.org/10.1186/s12909-016-0761-7>
- [2] Talib, Corrienna Abdul, Faruku Aliyu, Abdul Malik, and Kang Hooi Siang. "Enhancing Students' Reasoning Skills in Engineering and Technology through Game-Based Learning." *International Journal of Emerging Technologies in Learning* 14, no. 24 (2019). <https://doi.org/10.3991/ijet.v14i24.12117>
- [3] Halpern, Diane F. "Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring." *American psychologist* 53, no. 4 (1998): 449. <https://doi.org/10.1037/0003-066X.53.4.449>
- [4] Fong, Carlton J., Yughi Kim, Coreen W. Davis, Theresa Hoang, and Young Won Kim. "A meta-analysis on critical thinking and community college student achievement." *Thinking Skills and Creativity* 26 (2017): 71-83. <https://doi.org/10.1016/j.tsc.2017.06.002>
- [5] Suhaimi, Elmi Sharlina Md, Zuhazi Abdullah, Norazreen Muhamad, Nik Khadijah Nik Salleh, and Ahmad Affendy Abdullah. "FIGEE CARD: Pembelajaran Interaktif Kumpulan Berfungsi Kimia Organik: FIGEE CARD: Interactive Learning of Organic Chemistry Functional Groups." *International Journal of Advanced Research in Future Ready Learning and Education* 30, no. 1 (2023): 13-24.
- [6] Ibrahimi, Ainun Rahmah, Zamri Mahamod, and Wan Muna Ruzanna Wan Mohammad. "Pembelajaran abad ke-21 dan pengaruhnya terhadap sikap, motivasi dan pencapaian Bahasa Melayu pelajar sekolah menengah (21th Century Learning and the influence of attitude, motivation and achievements Malay Language Secondary School Student)." *Jurnal Pendidikan Bahasa Melayu* 7, no. 2 (2017): 77-88.

- [7] Lee, Kangdon. "Augmented reality in education and training." *TechTrends* 56 (2012): 13-21. <https://doi.org/10.1007/s11528-012-0559-3>
- [8] Abdel-Salam, Tarek, N. E. Sawaf, and Keith Williamson. "Robotics explorations to enhance information technology literacy in rural schools." *Journal of Communication and Computer* 6, no. 3 (2009): 55-63.
- [9] Saad, Sharina, Berlian Nur Morat, Amelia Abdullah, and Yasmin Farani. "Empowering ESL Learners: Unleashing Autonomy through Project-Based Learning." *International Journal of Advanced Research in Future Ready Learning and Education* 35, no. 1 (2024): 1-8.
- [10] Wheatley, G. H. "MEPS Technical Report." *Mathematics and Science Centre, Purdue University*, (1984).
- [11] Gagne, Robert M. *The conditions of learning*. Holt, Rinehart and Winston,, 1970.
- [12] Gagne, Robert M. *The conditions of learning*. Holt, Rinehart and Winston,, 1977.
- [13] Priemer, Burkhard, Katja Eilerts, Andreas Filler, Niels Pinkwart, Bettina Rösken-Winter, Rüdiger Tiemann, and Annette Upmeier Zu Belzen. "A framework to foster problem-solving in STEM and computing education." *Research in Science & Technological Education* 38, no. 1 (2020): 105-130. <https://doi.org/10.1080/02635143.2019.1600490>
- [14] Cook, Ruth E., and Brent D. Slife. "Developing problem-solving skills." *Academic Therapy* 21, no. 1 (1985): 5-13. <https://doi.org/10.1177/105345128502100101>
- [15] Abbott, Daisy. "Game-based learning for postgraduates: An empirical study of an educational game to teach research skills." *Higher Education Pedagogies* 4, no. 1 (2019): 80-104. <https://doi.org/10.1080/23752696.2019.1629825>
- [16] Lampropoulos, Georgios. "Educational benefits of digital game-based learning: K-12 teachers' perspectives and attitudes." *Advances in Mobile Learning Educational Research* 3, no. 2 (2023): 805-817. <https://doi.org/10.25082/AMLER.2023.02.008>
- [17] Aliyu, Hassan, Yasheni Raman, and Corrienna Abdul Talib. "Enhancing Cognitive Development in Learning Chemical Symbol and Periodicity through Instructional Game." *Online Submission* 2, no. 3 (2021): 285-295. <https://doi.org/10.46966/ijae.v2i3.115>
- [18] Zourmpakis, Alkinoos-Ioannis, Michail Kalogiannakis, and Stamatios Papadakis. "Adaptive gamification in science education: An analysis of the impact of implementation and adapted game elements on students' motivation." *Computers* 12, no. 7 (2023): 143. <https://doi.org/10.3390/computers12070143>
- [19] Jaarsveld, Saskia, Thomas Lachmann, Ronald Hamel, and Cees van Leeuwen. "Creative Reasoning: The case of generating an RPM item." *Creativity Research Journal* 22, no. 3 (2010): 304-319. <https://doi.org/10.1080/10400419.2010.503541>
- [20] Kidam, Kamarizan, Siti Aishah Rashid, Jafri Mohd Rohani, Hafizah Mahmud, Hamidah Kamarden, Fateha Abdul Razak, Nurul Nasuha Mohd Nor, and Nur Kamilah Abdul Jalil. "Development of Instrument to Measure the Impact of COVID-19 And Movement Control Order to Safety and Health Competent Person and Training Provider." *Journal of Advanced Research in Technology and Innovation Management* 2, no. 1 (2022): 22-28.
- [21] Dede, Chris. "Developing a research agenda for educational games and simulations." *Computer games and instruction* 3, no. 2 (2011): 233-250.