

# Gamification of Chemistry with Stoichio-TRI Riddle Card Game

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**Abstract:** *The complexity of chemistry serves as motivation to create innovative teaching and learning pedagogical approaches. This pedagogy includes the application of game mechanisms in the subject matter to enhance the processes enacted and to make education more interactive and engaging. It also fosters a positive learning environment, especially for the physical chemistry subject that involves various chemical reactions, formulas, calculations, and principles. The aim of this project is to evaluate the effectiveness of educational gamification as a medium for learning chemistry. It is focused on increasing the students' understanding and mastery of the chemical reactions and stoichiometry topic. The innovation known as the "Stoichio-TRI riddle" card game was designed based on a puzzle riddle embedded with the curriculum content from the selected topic. The game could promote the skill of critical Thinking, active Recall, and Interaction among students (TRI). The test population consisted of the current students at the International Islamic University Malaysia (IIUM) taking the Sciences foundation program. Data were gathered from students' pre-test, post-test of the stoichiometry topic, and evaluation form through online questionnaires. The result indicated that the "Stoichio-TRI riddle" card game is helpful in enhancing students' understanding of stoichiometry reactions in chemistry and contributes insights into optimizing educational strategies by emphasizing the role of active recall in fostering robust and enduring knowledge acquisition compared to the traditional lecture-based teaching model. Indeed, this innovation offers a promising approach to engage students in a more interactive and enjoyable experience.*

**Keywords:** Stoichiometry, Puzzle Riddle, Chemical Reactions, Gamification, Curriculum

## 1. Introduction

At the foundation level of education, subjects typically include fundamentals concepts in mathematics, language arts, science, and social studies. Students also develop basic skills such as reading, writing, and numeracy. The focus is on building a strong academic foundation and encouraging curiosity to prepare students for more advanced studies. STEM in education has the aim of preparing students to be competitive and ready to work according to their preferred fields (Rifandi & Rahmi, 2019). Chemistry education introduces basic concepts such as elements, compounds, and the periodic table. It act as the core of science that makes the knowledge of chemistry to be essential especially for those aiming to pursue careers in either the chemical industry or other scientific fields (Rosly et al., 2021). Understanding the properties of different substances and the fundamental principles of reaction govern the

chemistry subject. The curriculum expands to cover more complex topics, including organic and inorganic chemistry.

Educators are always searching for new ways of teaching because the current serious issue at schools is related to the student engagement and motivation. Majority of students believe that traditional schooling is boring and useless (Putz et al., 2020; Lee & Hammer, 2011). Thus, games have a strong ability to motivate individuals and it could drive students satisfaction during teaching and learning process (Yu et al., 2020). There are variety of gamification techniques that implemented and played by the students for the enjoyment and the chance to win. The use of educational games as learning tools promises advantages due to their abilities to teach and reinforce such as the opportunity to learn in multi-sensory, hands-on and in an experimental setting (Cheung & Ng, 2021). As a result, gamification have been searched as methods to boost the motivation of learners in educational contexts (Smith et al., 2022). However, developing a fully functional, highly engaging educational game is challenging, expensive, and time-consuming, and it usually focuses on a specific set of learning objectives that the game creator has selected. Thus, the educational game development can be improved through considering diversity of ideas, creative design and development methodologies development.

This introduction explores the intersection of gamification and card games as a powerful tool to make education more dynamic and enjoyable, ultimately promoting a deeper understanding of academic concepts. Card games can make complex subjects more accessible, helping students grasp and apply academic concepts in a practical and enjoyable manner. The innovation known as “Stoichio-TRI” card games that was designed based on puzzle riddle embedded with the curriculum content from the selected topic as it aims to help students have better understanding on the concept of stoichiometry in chemistry. The game may help students develop their critical Thinking, active Recall, and Interaction skills (TRI). In contrast to the traditional lecture-based teaching model, the gamification activity using "Stoichio-TRI" card games is helpful in enhancing student's understanding in reaction stoichiometry of chemistry and provides insights into optimizing educational strategies by highlighting the role of active recall in fostering robust and enduring knowledge acquisition.

The project was evaluated based on its impact on students' learning and engagement with their studies. The approach included a pre-test and a post-test assessment, then a questionnaire to acquire their feedback towards the game. Findings showed that the students feedback was positive and their understanding towards the topic boosted. It shows that the Stoichio-TRI has potential as an effective teaching tool.

## 2. Methodology

The game was designed as an approach to increase student understanding and abilities to master Reactions and Stoichiometry topic from Chemistry 1 (CHE 0315) course. This subject is a compulsory subject for all sciences course students from Centre for Foundation Studies, International Islamic University Malaysia. The experimental group of students were selected from students that are currently taking the course after they have completed their 8 contact hours of lecture including tutorial discussion on the topic. The participants were given with a pre-test to check their understanding level on the topic before adopting the gamification. The participants were divided to small groups for the running of the game. After the completion of the gamification session, the participants were administered with post-surveys and post-test. All questions in the card games are tailored with the syllabus of Chemistry 1 at CFS IIUM

which include both pre-test and post-test questions. We implemented Likert scale mechanism, as mentioned that the mechanism is among the most popular and foundational scaling method used in social science research (Taherdoost, 2019). The Likert scale has been devised by Rensis Likert in the 1932 for his doctoral thesis (Taherdoost, 2019; Likert, 1932). The questionnaire materialized interval data of 5-points scaling from very poor, poor, fair, good, and very good. In the post-surveys, the students were given several additional questions that were specific to their experience playing with this Stoichio-TRI riddle game card in their group. Finally, the data was analysed to observe the effectiveness of this gamification approach in enhancing students' understanding, specifically for topic of Reactions and Stoichiometry. The data analysis further discussed in the results and discussions below:

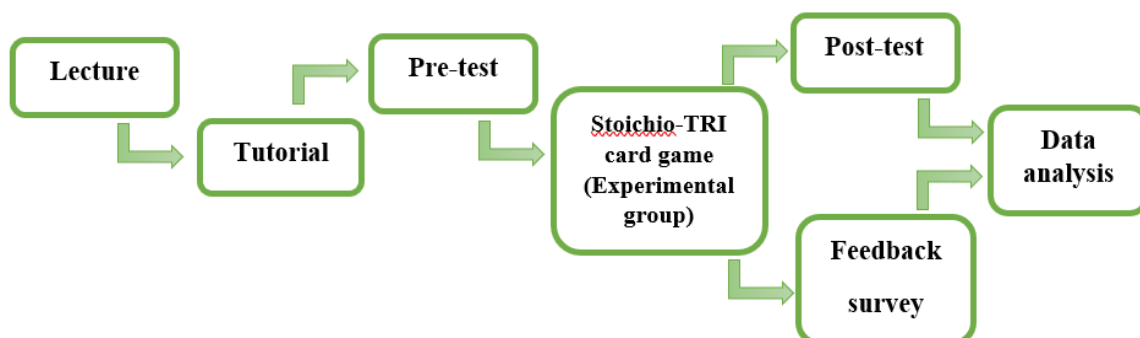


Figure 1: The Research Framework on The Stoichio-Tri Gamification Implementation

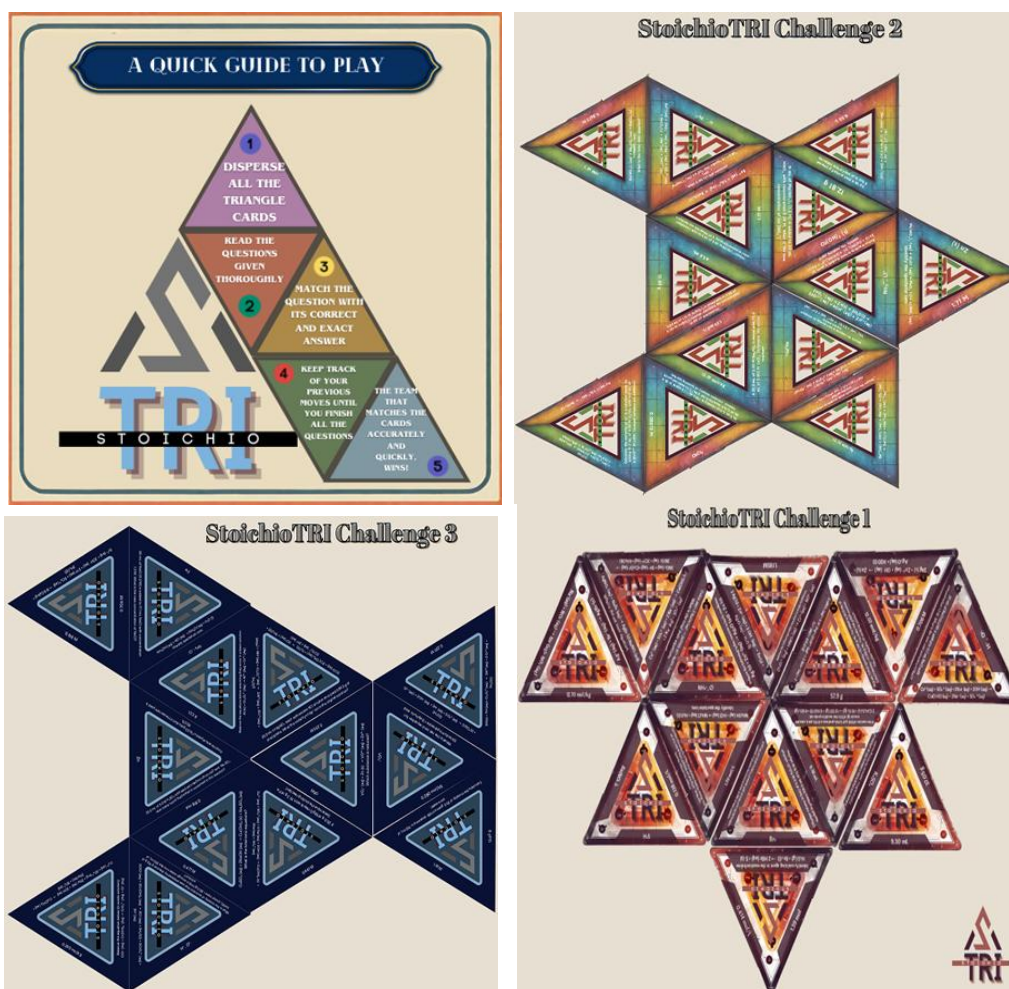


Figure 2: A brief guidance for Stoichio-TRI game in the card set and the answer on the arrangement of stoichio-TRI cards



Figure 3: Simulation of Students Chemistry I Playing Stoichio-Tri Game.

### 3. Results and Discussions

In this present work, the effectiveness of educational gamification as a medium for learning chemistry using card games was evaluated. A survey was conducted on 49 engineering and computer science's students who had taken part in Stoichio-TRI riddle game card and participated in the survey. The figures generated below are from the surveys in form of Likert scale, 1-5, from very poor, poor, fair, good and very good (Likert, 1932). The data was later be analysed to evaluate the effectiveness of the gamification to improve learning. The aim of this project is to present an interactive support module and an enjoyable learning environment in Stoichio-TRI riddle. Apart from that, efficacy of the Stoichio-TRI riddle card game among students taking the Chemistry subject can be assess as well as to evaluate overall feedback towards gamification integration in teaching and learning.

#### Learning Quality

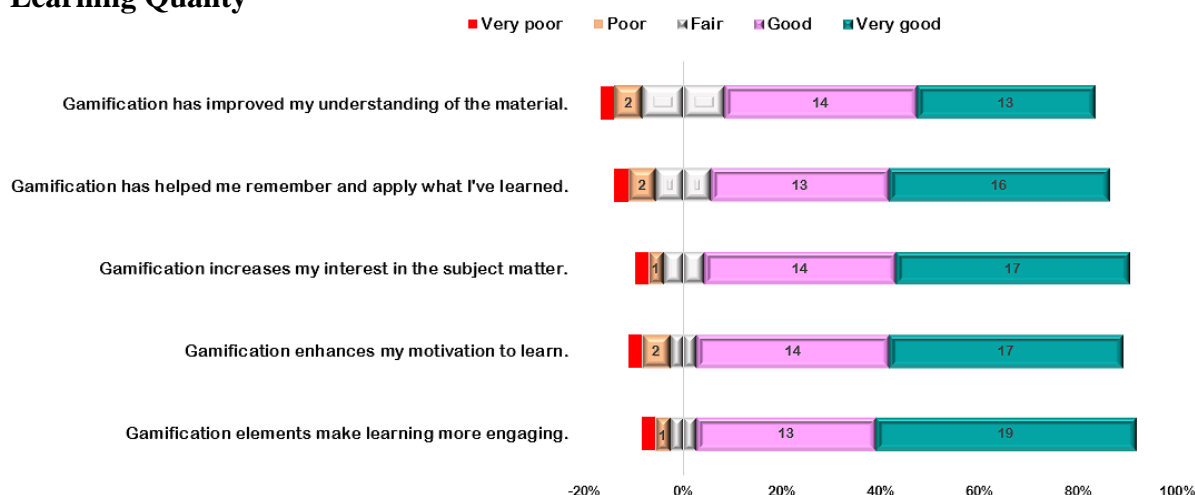
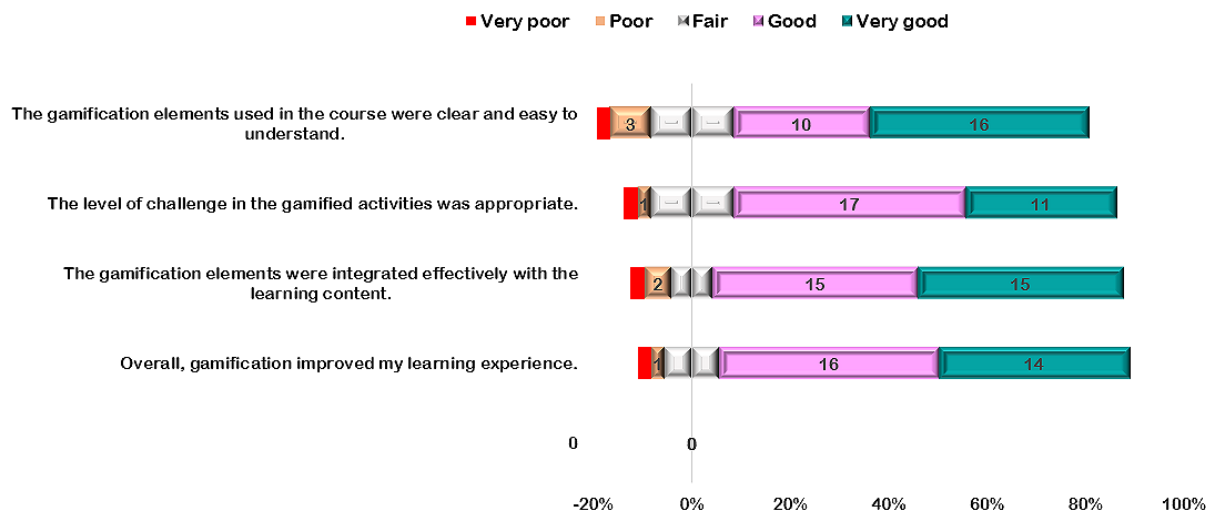


Figure 5: The graph about the response of students on perception of Stoichio-TRI riddle card game on their learning quality.

Based on the Figure 5 above, most of the students agreed by taking part in Stoichio-TRI riddle card game can improve their learning quality as well as the gamification elements in learning help to pick interest amongst students by making the learning more engaging and exciting. The results showed that incorporating gamification into learning, improve stoichiometry topic

understanding, subject retention time, interest and motivation to learn as it is more engaging. The findings corroborate with study conducted by Mee Mee et al., (2020) that revealed learning in gamification environment able to help the student to grasp the tough subject such as Stoichiometry.

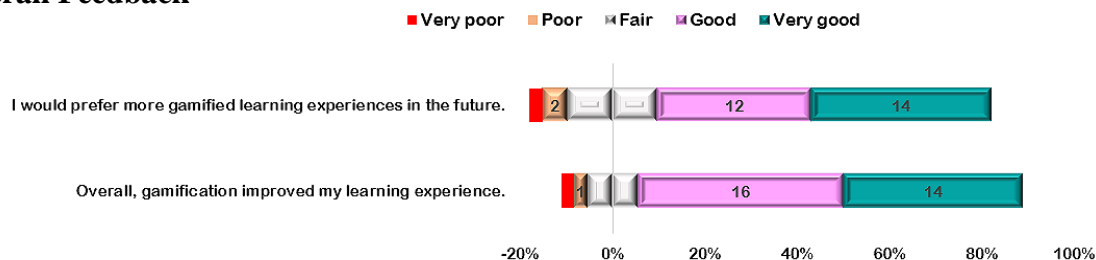
## Gamification Element



**Figure 6: The graph regarding the responses of students on perception of the gamification elements in Stoichio-TRI riddle card game.**

Figure 6 shows most of the students also agreed Stoichio-TRI riddle card game is appropriate and suitable for students as one of the tools to enhance learning. Based on the responses, they agreed that level of challenge in Stoichio-TRI riddle card game was acceptable, and the gamification elements used were clear and easy to understand. Additionally, the influence of challenge-based gamification towards the analytical thinking concept was identified, and the engagement and inquisitiveness levels of quizzing as gamified platform were appraised (Anunpattana et al., 2021). Overall, the gamification elements used were implemented effectively with the content of the stoichiometry topic and improve the students' learning experience. The result is supported by (Serna-Gallén et al., 2022) that conclude that gamification serves as effective approach for solving chemistry questions including stoichiometry problems.

## Overall Feedback

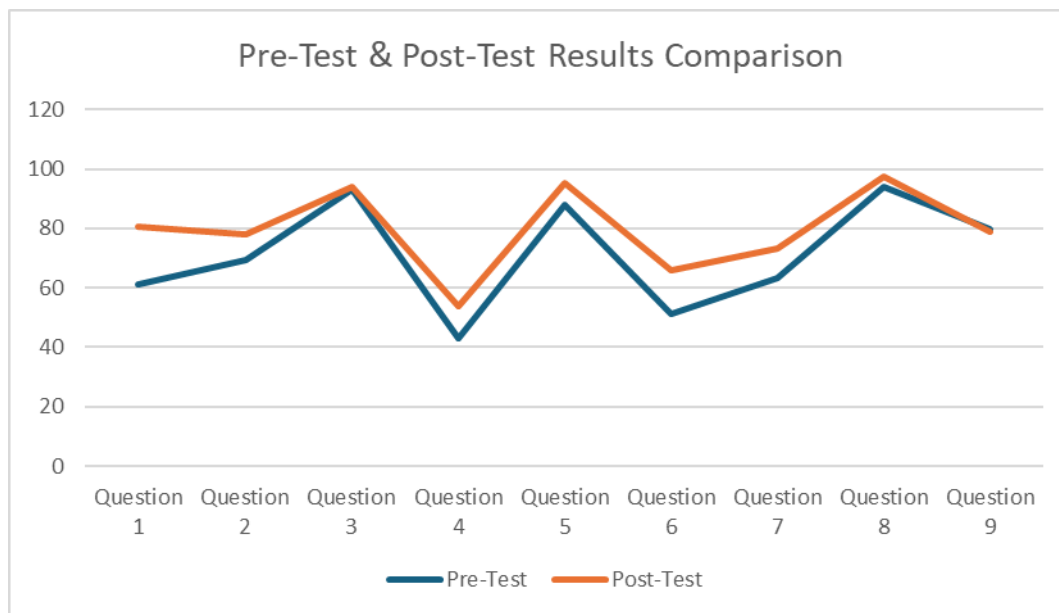


**Figure 7: The graph shows the overall feedback from students on perception of the Stoichio-TRI riddle card game**

From the Figure 7 above, majority of the students who had taken part in the Stoichio-TRI riddle card game and surveys agreed that the gamification able to give positive impact to improve their learning experience and impression as the gamification can make the learning more enjoyable and favourable. The students also preferred that in the future, the learning should

include the development of more prototypes for a game-like educational system that can help to provide useful tool for students about their learning progress (Cheong et al., 2014). These findings coincided with what presented by Chans & Portuguese Castro, (2021) that gamification improve the learning process and enhance the understanding of the subject.

#### 4. Result of the Post-Test and Pre-Test



**Figure 8: The line graph shows the Pre-Test and Post-Test achievement.**

Based on the graph in Figure 8, the increase in the percentage on students' performance in each question regarding topic after the implementations of Stoichio-TRI card game. As a final observation, it is proven the effectiveness of gamification learning that been implemented in Stoichio-TRI riddle card game was able to enhance student learning to achieve satisfying results. These collective discernments postulate gamification as a cogent catalyst for improving the chemistry learning outcomes by advocating motivation, engagement, and academic achievement (Othman et al., 2024). Students who expressed elevated levels of dedication and engagement throughout their participation in gamified learning exposures demonstrated a greater penchant for retaining acquired proficiencies at a superior level (Khasawneh et al., 2024). By integrating gamification into education, not only the procurement of knowledge is promoted, but likewise exploration, experimentation and problem solving, essential aspects for cognitive development and powerful retention of knowledge (Morales-Nava et al., 2024; Hamari et al., 2014). This gamification improves the learning experience whilst positively impacts the formation of fundamental transferable skills, for instance, critical thinking, collaboration and recognition for students' strengths. These skills are revealed as critical elements in nurturing students to face the dynamic challenges of the 21st century (Morales-Nava et al., 2024; Landers & Landers, 2014). Moreover, this gamification elevates the way for students and lecturers to remain associated to each other (Chans & Portuguese Castro, 2021; Landers & Callan, 2011).

#### 5. Conclusion

In this project, an educational physical gamification program in the form of a card game has been designed, implemented, and evaluated. The analysis showed that the implementation of Stoichio-TRI riddle game card helped students gain a better understanding of Reactions and

Stoichiometry topic. The participants not only performed better in their post-quiz result, but they felt more confident about the topic after engaging in the gamification session. The process of knowledge transfer also occurred during the session as the winner is based on the whole group achievement. Also, these students enjoyed the game enough as it increases their motivation in solving all the questions to complete their puzzle riddle card. These results suggest that a well-constructed game card can be a useful tool to teach the topic that involves a lot of equations, formula, and calculation. Even though the assessment provided encouraging results, there is still more research and development that needs to be done especially on the game running procedures and list of questions involved. Finally, because of the encouraging results of this study, this riddle card game can be expanded to another topic in the Chemistry 1 (CHE 0315) course and the future is to commercialize the prototype open to all chemistry educators as a teaching tool. The game has the potential to be developed into an online game with the right tools and software, further able to be commercialized.

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