



Leveraging Gamification to Foster Critical thinking and Problem-solving skills in Chemistry Education in High school

Gulnaz Kamal

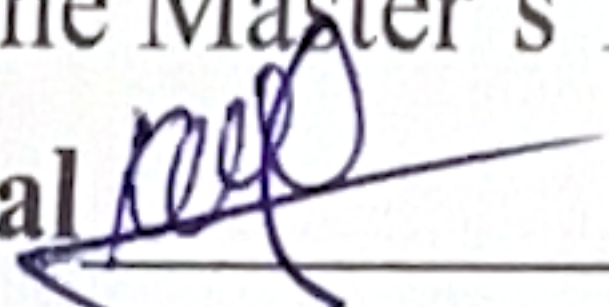
A thesis submitted to the School of Education and
Humanities in partial fulfillment of the requirements
for the degree of

MASTER OF EDUCATIONAL SCIENCES
in 7M01502 – Chemistry

«SDU University»
Department of Pedagogy of Natural Sciences

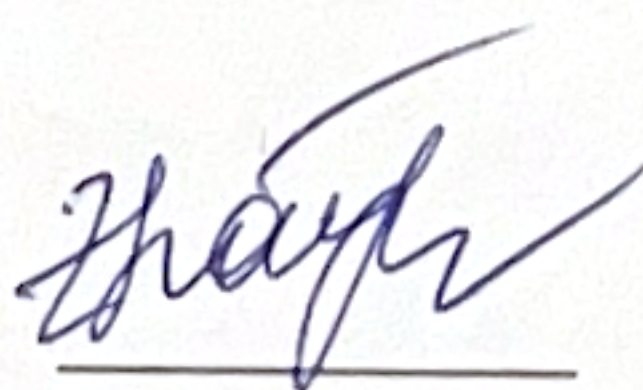
Thesis Supervisor: PhD, Associate
professor, Zhangyl Abilbek

«SDU University»
School of Education and Humanities
Department of Natural Sciences Pedagogy

This is to certify that the Master's Thesis of
Gulnaz Kamal 
has met the thesis requirements of SDU University.

Approved by

Thesis Supervisor



PhD, Associate professor,
Zhangyl Abilbek

MEd Program Coordinator



PhD, Associate Professor
Satilmis Yilmaz

Head of Department



PhD, Associate professor,
Zhangyl Abilbek

Dean of School

PhD, Assistant Professor,
Dana Moldabayeva

Kaskelen, 2026

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LIST OF ABBREVIATIONS

STEM - Science, Technology, Engineering, Mathematics

CT - critical thinking

PS - problem-solving

ABSTRACT

This study examined the effectiveness of gamification in fostering critical thinking and problem-solving skills in high school chemistry education in Qazaqstan. Using a mixed-method design, 92 participants across three school settings were divided into experimental and control groups. Mann-Whittney U tests revealed statistically significant differences in post-test scores in favor of the experimental group across all contexts ($p < 0.05$; critical thinking skill: $U = 475$, $p < 0.001$; problem-solving skill: $U = 221$, $p < 0.001$). Thematic analysis of semi-structured interviews supports these findings, with participants reporting enhanced motivation and deeper cognitive engagement. The study concludes that gamification is an effective pedagogical strategy for developing critical thinking and problem-solving skills in high school chemistry education.

Keywords: gamification, critical thinking skill, problem-solving skill, chemistry education, chemistry, high school, Qazaqstsan.

АНДАТПА

Бұл зерттеу Қазақстандағы жоғары сынып оқушыларының химия пәнінде сыни ойлау және мәселені шешу дағдыларын геймификацияны қолдану арқылы жоғарылатуды зерттейді. Аралас тәсіл зерттеуін қолдана отырып, үш мектептен 92 қатысушы зерттеу жұмысына тәжірибелік және бақылау тобына бөлініп қатысты. Мэнн-Уитни U анализін қолдана отырып, пост-тест нәтижесі бойынша барлық мектептегі тәжірибелік және бақылау топтарының арасындағы статистикалық айырмашылық анықталды ($p < 0.05$; сыни ойлау қабілеті: $U = 475$, $p < 0.001$; мәселелерді шешу дағдысы: $U = 221$, $p < 0.001$). Семи-структуралы интервьюден алынған тематикалық талдау анализден алынған нәтижелерге сай келді. Зерттеу геймификацияның химия пәнінде жоғары сыптарда сыни ойлау мен мәселелерді шешудағдысын дамытуда тиімді педагогикалық стратегия екенін тұжырымдайды.

Кілтсөздер: геймификация, сыни ойлау дағдысы, мәселелерді шешу дағдысы, химия пәнінен білім беру, химия, жоғары сынып, Қазақстан.

АННОТАЦИЯ

Данное исследование изучает эффективность геймификации в развитии навыков критического мышления и решения проблем на уроках химии в старшей школе Казахстана. В рамках смешанного метода исследования 92 участника из трех школ были разделены на экспериментальную и контрольную группу. Анализ Мэнн-Уитни U выявил статически значимые различия в пользу экспериментальной группы от контрольной группы при пост-тестах во всех школах ($p < 0.05$; навык критического мышления: $U = 475$, $p < 0.001$; навык решение проблем: $U = 221$, $p < 0.001$). Тематический анализ семи-структурного интервью подтвердил эти результаты. Исследование заключает, что геймификация является эффективной стратегией для развития критического мышления и решение проблем навыков в курсе химии старшей школы.

Ключевые слова: геймификация, навык критическое мышление, навык решение проблем, химическое образование, химия, старшая школа, Казахстан.

INTRODUCTION

The significant growth of technology and variety of gadgets have improved the quality of life, easing all kinds of daily chores. Amid this growing ‘easiness’, the new generation has lost most of the vital skills known as critical thinking and problem-solving. These skills become more consciously ingrained in a person’s consciousness during adolescence and high school. Using gamification in high school chemistry can help fill these gaps in students (Kamal, 2025).

The peak of technology use and the origin of this problem date back to 2019, during the quarantine that followed the first global outbreak of the coronavirus. To address learning challenges, all educational institutions transitioned to online learning, giving students greater freedom. This opportunity led to various tricks among students: using ready-made materials, cheating, not thinking through solutions independently and the ease of accessing materials via gadgets, which led to health risks when used longer than the allotted time. At the same time distractors, including videos, social media, cartoons and scrolling, increased significantly. Due to the increased popularity of these factors, students mostly perceive the negative impact of social media, leading to a decline in their academic performance (Rithika, 2013; Kamal, 2025).

Negative impact and deterioration in academic performance are not the primary consequences of addiction. Before reaching this stage, students clearly experience decreased motivation, loss of independent study, disfocus, and misplaced priorities, amidst the anxiety generated by ‘successful people’ on social media. Furthermore, the ‘light dopamine rush’ received from scrolling through social media replenishes the student’s dopamine stores, leading to ‘laziness’, which is clear when performing even the mundane tasks. The resulting addiction will lead to sleep problems, social isolation, and unproductivity, increasing cyberbullying and mental health issues (Khare, 2023; Kamal, 2025)

This section provides information about the introduction, including the background and context of study, the research problem, the goal and objectives, research questions and hypothesis, significance, limitations (Kamal, 2025).

One of the learning strategies used in online learning is gamification, which has attracted much interest in recent decades due to its potential impact on improving user engagement and enjoyment. Gamification is a method in which various game strategies and mechanics are used in non-game contexts to increase student's engagement and motivation. This methodology seeks to engage students in an interactive system that motivates them to participate in the process of a particular activity (Chans, 2021; *ibid.*).

Chemistry represents an intricate yet important field of study within science. The subject goes far beyond rote memorization of the periodic table and equation balancing. Instead, chemistry requires students to think through problems where certainty is not always possible, discern causation through unseen molecular reactions, and construct arguments to explain things not visible to the naked eye. But this process of thinking is not simply academic. Rather, it represents the core of how scientists think. Still, modern chemistry education shows inconsistency in how it is practiced, as lecturers teach to a room full of disengaged students while practice problems are drilled without regard for the logic behind them.

This mismatch between what chemistry demands and what traditional teaching offers is not an abstract issue. It is evident in learners who know Le Chatelier's Principle but cannot utilize it in dealing with novel chemical equilibria problems and in learners who get stuck in answering an experimentally oriented question due to a lack of ambiguity management training.

Gamification was chosen to close this gap. By designating particular game mechanics such as points, levels, achievements, challenges, leaderboards, and instant feedback, these mechanics become flexible according to the topic at hand. In addition, there is a significant amount of research demonstrating an effect where engagement and motivation improve based on the idea that learning is not mandatory. The logic behind it suggests that games engage people, make them care about results, and encourage perseverance more effectively than, for instance, worksheets. As an example, solving the chemical equation becomes more meaningful when it affects the student's place in the class leaderboards.

Many studies conducted on gamification in education have focused on evaluating the effectiveness of the use of gamification in improving students' enjoyment, attendance, or motivation (Dicheva et al., 2015). Although these studies have produced important findings, more needs to be done. When a student enjoys a gamified chemistry class and leaves without any improved analytical ability, he or she is merely amused, but not educated. The gap that will be explored in this study relates to the influence of gamification on critical thinking and problem solving in secondary school chemistry. Whether gamification makes students think better, not merely feel better about thinking will be the findings of the given study.

Aim of the study is to investigate how gamification can be effectively leveraged to foster students critical thinking and problem-solving skills among high school chemistry students, and to understand which gamification elements drive those outcomes and how students experience the process.

The study is guided by four **research questions**, each addressed through a specific method:

1. How can gamification be effectively leveraged to foster students critical thinking skill in chemistry education in high school?
2. How can gamification be effectively leveraged to foster students problem-solving skill in chemistry education in high school?
3. Which specific gamification elements are most effective for developing critical thinking and problem-solving skills in chemistry education in high school?
4. How do the students perceive the use of gamification in chemistry education in high school?

Objectives are:

1. To assess the impact of gamification on students critical thinking skill in high school chemistry education through pre- and post-test comparisons.

2. To assess the impact of gamification on students problem-solving skill in high school chemistry education through pre- and post-test comparisons.

3. To identify which specific gamification elements are most effective in developing critical thinking and problem-solving skills in chemistry education in high school.

4. To explore student's perceptions and experiences regarding the use of gamification in high school in chemistry education.

Hypotheses of the given study are shown below:

Null hypothesis: Gamification does not significantly foster critical thinking and problem-solving skills in high school chemistry education.

Alternative hypothesis: Gamification significantly fosters critical thinking and problem-solving skills in high school chemistry education.

The significance of this research is layered. For the classroom teacher, the study offers practical guidance based on research about what gaming practices result in cognitive benefits. From the perspective of curriculum developers and administrators, the research contributes to an increasingly larger body of knowledge that could be used to make decisions regarding science education in high schools. And for the broader field of educational research, it insists on a distinction that too many studies have blurred: the difference between a student who is engaged and a student who is thinking.

This study's **theoretical contribution** adds to what is already known by looking at a part of education that hasn't gotten much attention before. Specifically, it looks at how to intentionally develop critical thinking and problem-solving skills in high school chemistry classes. While researchers have looked at gamification in many different areas of learning, there's less focus on how it can build these higher-order thinking skills in chemistry. The study helps grow our theoretical understanding of how gamification links up with cognitive development and subject-specific teaching techniques. It lays down some groundwork for future research too, helping to find reliable ways to teach analytical and problem-solving skills in high school settings.

This study's **practical contribution** is a ready-to-use instructional manual for chemistry teachers who work with high school students. It includes 16 games made to boost critical thinking and problem-solving in their lessons. What sets it apart is its bilingual design - in both Qazaq and English - which fits well in Qazaqstan's schools and makes it useful for an international audience too. These games are super easy to use, needing little prep time, and can be slotted into any lesson plan with ease. By combining theory with practical use, the manual gives teachers a set of tools based on real evidence. This lets them go beyond old teaching methods and get students engaged in more complex thinking through fun, game-based activities.

LITERATURE REVIEW

This literature review examines the scholarly evidence of three basic themes based on implementation of gamification to increase critical thinking skill in chemistry education and the contribution of gamification to problem-solving skill development in chemistry education, gamification's effect on critical thinking and problem-solving skills in other subjects. Each of these themes is addressed in a dedicated section drawing on recent empirical research, with the aim of constructing the theoretical and evidential foundation for the present study's investigation of gamification's impact on critical thinking and problem-solving in high school chemistry across three institutionally distinct school settings (Kamal, 2025).

Gamification is broadly defined as the integration of game design elements into non-game contexts, with educational settings being among its most widely studied application areas. The growth of gamification research in educational settings has been substantial over the past decade, with a growing application in STEM and formal K-12 education, as well as increasing relevance of online and personalized learning environments, through significant research gaps remain, particularly concerning the long-term impact of gamification and isolated effects of individual game elements (Gini et al., 2024).

Importantly, in underrepresented science disciplines like chemistry, conducting more research is especially critical to understand the impact of gamification (Kalogiannakis et al., 2021). A meta-analysis focused specifically on chemistry education confirmed this potential, finding that interactivity in combination with multiple representations in game-based learning requires learners to connect all three levels of chemistry knowledge and switch from one level to another, which may help overcome learning difficulties, while real-time feedback enables learners to identify chemistry content they may be struggling with (Hu et al., 2022).

1.1 Critical thinking skill in Chemistry Education

A growing body of evidence links gamification to the development of critical thinking skills. Research employing a pre- and post-test approach revealed statistically

significant improvement in student's post-test scores across all critical thinking domains, indicating that gamification positively influences conceptual retention and cognitive development among Grade 9 students (Khattib, 2024). At the level of STEM education more broadly, gamified STEM activities may enhance problem-based learning but focuses on active learning in which students work with different tools and resources to solve their problem (Asigigan, 2021).

Teachers have observed that while students enjoy themselves and interact during gamified activities, new skills such as critical thinking and creativity are developed, improving their memory capacity (da Silva et al., 2025). It supports theories suggesting that the inclusion of story, competition, and creativity in games tends to encourage the involvement of higher-level cognitive functions.

This aspect of how gamification interacts with critical thinking and problem solving is equally well supported by the literature. As an instruction technique that focuses on student engagement, gamification is a promising strategy that can motivate students to develop problem-solving skills, making it a valuable improvement in teaching procedures (Zeng et al., 2024). This idea is additionally backed up by empirical evidence obtained in the context of secondary schools, which reveals a significantly positive impact of gamification on problem-solving skills in secondary schools, evidenced by the test scores after treatment (Xavier, 2024).

What has not been proposed any longer is the idea that gamification produces improvements solely in the realms of critical thinking and problem solving. A meta-study confirms this trend, as gamified students show tangible improvement in their higher-order cognitive functions. The process at work here is the usage of the knowledge obtained through new concepts within active learning rather than passive learning (Zheng et al., 2024). However, the scope of research expands further than merely cognitive abilities; behind every learning experience, there is the aspect of affective functions, where progress is slower to be made.

A departure from the traditional approach was followed by Hyung (2025), as the researcher looked into the effects of gamification on students' emotions during

instruction based on self-determination theory. For this purpose, the author utilized the Classcraft program alongside other traditional gaming components like points, badges, and leaderboard rankings. However, the implications were far-reaching: gamification not only helped boost students' positive feelings, but it also served to reduce negative feelings, with notable decreases in levels of anxiety and hopelessness. Even more interesting, however, was that which existed below the surface of the data: Learning styles did not serve as a neutral factor, but actually affected all aspects of emotional experience. Sensory learners had more success emotionally thriving in situations where direct interaction was possible due to the stimuli involved, while intuitive learners found relief through the logical structure of gamification. The same intervention, in other words, reached different students through entirely different doors.

The broader landscape of gamification research in science education has been systematically explained by Alahmari et al. (2023), whose review of 31 studies indexed across international databases found that most gamification interventions produced positive outcomes for science education students. The review confirmed that gamification was most commonly employed to enhance student's learning skills across various science fields, while also highlighting that certain areas within science education remain insufficiently investigated. The authors concluded that while the evidence base is encouraging, further research is needed to develop across the full breadth of science disciplines. This finding is directly relevant to the present study, which addresses one area. And contributes empirical evidence to a literature that thus far lacked sufficient subject-specific and context-specific investigation.

According to scholars, gamification can turn traditional educational processes in chemistry into engaging and student-focused learning environments that will foster critical thinking and problem-solving skills in young people. As mentioned by Jenkins and Mason (2020), the implementation of gamification in active learning frameworks helps to achieve better conceptual understanding and active involvement in general chemistry courses. Moreover, the bibliometric mapping of gamification in chemistry performed by Dolničar (2025) indicated an increasing number of publications

dedicated to this phenomenon and confirmed gamification as a new trend in educational practice, which is important because of the importance of developing cognitive skills in the high school context.

Motivation and engagement have become regular outcomes of various types of studies on gamification. For instance, Suryapranata et al. (2023) showed how gamification can be used to motivate high school students to study chemistry using the visual novel method. Another study conducted by Hallal (2022) proved that the utilization of gamification through the tool known as ChemiPuzzle led to positive changes in students' motivation and enhanced their ability to understand structural elements of organic compounds. Additionally, Ambarwati et al. (2022) proved that gamification could also be applied together with problem-based learning, which led to improvements in mathematical problem-solving skills. Consequently, gamification may serve as an effective tool to motivate students and engage them in learning different subjects.

1.2 Problem-solving skill in Chemistry Education

In addition, many studies have proven the potential of gamification to help students develop critical thinking skills and become efficient problem solvers. The same conclusion was drawn by Benjamin (2024), who discovered that gamification improved students' perception of engagement and problem solving that were crucial for success in chemistry studies. In another study, Feng et al. (2024) performed a systematic review of existing literature and found evidence of the positive influence of gamification on the problem-solving skills in students regardless of subject. Thus, the use of gamification techniques may contribute to the improvement of young people's cognitive functions.

Recently, several researchers focused on gamification as a means for cultivating higher-order cognitive skills in high school students. Specifically, Olaya-Abril (2026) proposed ESTOPA as a low-cost method of developing critical thinking and problem-solving skills in the field of chemistry. Machmud et al. (2023) developed a constructivist gamification environment and emphasized the importance of introducing

ill-structured problem-solving tasks to enhance students' critical thinking. These examples show that gamification is quite flexible and can be adjusted to meet various needs in terms of educational practices.

At the same time, it is essential to focus on the narrative-driven gamification methods to promote cognitive engagement of students. According to Jiménez-Valverde (2025), combining a narrative and gamification strategies could improve conceptual understanding and applications in chemistry. In particular, embedding a certain problem-solving task into the storyline is associated with increased development of critical thinking in students as they would solve a particular problem within a certain situation.

Chang et al. (2021) proposed to improve the educational strategy by using gamification to overcome the difficulties in teaching. The article also noted that previous studies in the field of gamification have been successful in showing students' professional abilities with an increase in their activity during the lesson. These findings prompted the creation of gamification in undergraduate chemistry courses called Fundamental of the Structure and Transformation of Matter and Analysis of the Structure and Transformation of matter in the 2020-2021 academic year in Mexico. According to the description, three principles were used for their gamification system: autonomy, relatedness, and competence. In the project, long-, medium-, and short-termed activities with tools such as survey and pre-, post-tests were used to achieve goals and obtain answers to research questions. In the results obtained from pre-, post-tests, at the end the number of students who got higher scores increased. In the survey, most students wrote about a good disposition to gamification, describing it as a tool to be focused and motivated, and effective for studying. As the authors mentioned, the most effective and interesting in the gamification methodology for students was tokens, promoting students' participation in each lesson. Otherwise, the least effective was mind maps due to the heavy workload along with other subjects. In conclusion, authors propose using the gamification methodology in different circumstances, classes and subjects (Kamal, 2025).

In the case of Lutfi et al. (2023), the objective was to obtain a game for use on hydrocarbon learning media based on the effectiveness, practicality, and validity of the game. To achieve this goal, the authors collaborated with students from East Java High School-Indonesia. The research and development (R&D) method consisting of three steps, such as 1) Preliminary Study, 2) Product Development, and 3) Testing was used to create the game. To check the reliability of the results in the article, calculations were made using SPSS program assistance. During the verification of the calculations, it was proven that the Hydrocarbons Chem-Rush game is valid for use, gaining validity with a range of 73.33% - 93.33%. Thus, the authors showed accurate data for use in further new projects. The created game showed high results when checking the student's learning outcomes using the Kolmogorov-Smirnov Test. The method of checking the motivation of students was a questionnaire with four aspects, all aspects of students after the game showed results above 70%. According to the author, despite the age of the high school students love games, in connection with this, the created new game was crowned with success and can be used as an alternative version of teaching chemistry (*ibid.*).

Othman et al. (2024) article started research from the studying student's responses to the integration of gamification in science education. Based on the ADDIE method, CHEM-XPLORACE activities were created, consisting of four games, each of which represents different aspects of chemistry, from creating songs with chemical terms to correctly forming chemical terms. The data were obtained from pre-Diploma in Science students at Universiti Teknologi MARA. To achieve the goals and verify this, pre-, post-survey was used. The results of the work showed a positive impact on students, as well as an increase in understanding of the importance of chemistry in everyday life. Despite this, limitations were identified during the work, the first one is efficiency. The authors noted that it will be different due to different student populations and educational contexts. During the survey, a small decrease in student interest was noted, while it is difficult to identify more accurate data due to the study being conducted without a control group. These shows that it is worth considering

many factors that influence student's perception. The results obtained, despite the limitations, show that CHEM-XPLORACE develops group work, communication, leadership, and improves the effectiveness of teaching chemistry using visual and kinesthetic elements (*op cit.*).

1.3 Gamification's effect on Critical thinking and Problem-solving skills in other Subjects

The article by Al Ghawail et al. (2022) aims to create different game designs in the technology of Kahoot! In addition, the article seeks ways to determine the effective ability of students to learn in-, out-of-class and the use of psychology theory in connection with the motivation of students. As a sample, first-year students of pharmacy science college of Alasmarya Islamic University, Libya were chosen. The research controls the process of education with the help of game based learning. In the process of data analysis, the use of Likert scale, Schronbaskhs alpha, IBM SPSS Statistics 20.0 software is noted. The obtained data comes to the fact that Kahoot! provides more constant learning in comparison with traditional methods, helping to teach easily, and facilitating the process of obtaining information for teachers on how many questions the student answered correctly. The authors write that this will help to determine the level of the student at the moment. The article in the results showed greater involvement of students in lessons, high indicators of competition, which led to diligent preparation for lessons. In addition, competition among students was consistent in the findings. In the limitations, the authors mentioned that due to the number of samples, the results obtained do not apply to all lectures using the Kahoot! technology. Interesting moments that occurred during the use of the Kahoot! technology increased the fast-paced learning environment and competition among students, thereby having a positive impact at the end of the research (*op cit.*).

da Silva Junior et al. (2025) in his article took as a goal to motivate students in low positions, thereby improving the learning of students. The most interesting is the training of students to determine the chemical composition of an unnamed drug. Chemistry and Pharmacy undergraduate students were chosen as the object. The game

has three different rankings, during the game the player receives rewards, thereby increasing his ranking. A distinctive feature of the game is the "Unsuccessful student". The meaning is to choose one student as unsuccessful from the top five students, as a reward gives chocolate. According to the author, this increases the motivation of students to reach the top, thereby becoming unsuccessful. Reading the article, you can see that the authors relied on popular games among students, thereby drinking the service of their own game. For example, this can be seen in the change of avatars, or in the final boss. The rewards received were different: for students in low positions, they added more points than to other students. However, the authors claim that there was no complaint about this because all players were given extra points. And at the end of the semester, the top players were presented with a real trophy in recognition of their victory. To test the effectiveness of the game, the authors used the User Engagement Scale (UES-SF). When comparing traditional methods with the game, there was not much difference. There is several limitations are shown. Firstly, having changed traditional methods with a dynamic game, students remained under pressure due to the imposed dynamism. Secondly, the number of students who chose traditional methods calculated the inconveniences of gamification as little time to solve problems, learn new content, and the performance of students. In conclusion, the authors can change the game in the desire of students (*op cit.*).

In most cases, there are a lot of "gaps" in the research areas, and gamification technology is no exception. In the Swacha (2021) article, the objective is to find such holes and close them. To begin this, it was decided to make a survey consisting of three parts. In the first part, the number of publications in three sites was analyzed. Google Scholar showed the largest publication in 2019. But Scopus was chosen for further analysis. The author explains this by the fact that there are articles that can answer all questions. The main analysis shows that the USA and the UK have the largest number of publications. As an area of most interest in gamification and education was computer science. And the most common type of publication is a conference. The author briefly explained the results of the mentioned lack of dominance between institutions in

publications, and there are no holes between frequent authors or leaders. Many situations means that the author is a major participant in the field of gamification in education. This is a method of effective research communication (*ibid.*).

In this work, Yıldırım et al. (2021) examines the elements for effective integration of gamification into the educational process. To identify the results, the author decided to use the meta-analysis method. The object was more than 3,000 students from different countries. The study was conducted using different games in different concepts. Each game included different elements, such as motivation, relativity, dynamics, aesthetics, and so on. In identifying the results, a common effect size value was used, the resulting figure showed a positive effect on student achievement. In general, using Hedges' g value's omega square, 7.2% positive value was calculated, which increased academic achievement (*ibid.*).

The Murillo-Zamorano et al. (2023) article explores the gamification gap in learning by linking engagement, knowledge, and satisfaction of students with gamification that has not been explored in single research. As a gamification tool was chosen The ECon+Star Battle from the teaching-learning process -The 8-Pointed Higher Education Gamification Star-. This method was conducted in classroom and extracurricular gamified activities for the Macroeconomics class for 15 weeks and 60 hours. The participants were in groups of 3-4 students. During the experimental part of research 5 topics from the syllabus of the course were covered. The results showed that gamification would directly affect the level of knowledge and engagement; the indirect effects of gamification were shown in the students' network. In conclusion, this piece of paper shows the impact of gamification does not work consistently in the long term when students are not satisfied with the implementation of gamification (*op cit.*).

The article of Nazneen (2024) describes the changes in students' attitudes towards gadgets that attract their attention. The root of this problem is the main reason for socialization today. The article discusses the introduction of gamification as a way to attract students' attention, develop critical thinking, and thus improve thinking, logic, and concentration. The gamification strategy was applied to 150 college students in

Aurangabad. After passing the preliminary test, the students were randomly divided into control and experimental groups. After the study, the analysis showed that the indicators of critical thinking, decision-making and problem-solving were significantly higher in the experimental group compared to the control group. The average values of these indicators were higher compared to the t-value. In conclusion, it has been proven that the inclusion of gamification in the curriculum will help students actively participate in lessons, while strengthening teamwork and competitive spirit (*ibid.*).

The article by Ahmed et al. (2025) is devoted to the problems of online education for university students; the increased demand for online education in the field of natural sciences has led to unprecedented problems. Developing critical thinking in the study of natural sciences is a fundamental skill, but online learning does not fully meet this need. Gamification was used as a suitable problem-solving strategy. Although most studies demonstrate the positive effect of gamification in online learning, the effectiveness of the strategy depends on factors such as student demographics, prior knowledge, and the subject being taught (Dichev and Dicheva, 2017).

The study was conducted quantitatively using surveys. Six hundred students from three universities were selected: University of Ilorin, Kwara State University and Al-Hikma University, with 200 students each. The data collected from the students was divided into research questions. All questions related to critical thinking received positive answers. In conclusion, this topic demonstrated the effectiveness of gamification in online science education, and the effectiveness of the strategy depends on student motivation and learning style (Kamal, 2025).

In the article of Hursen (2019), the authors begin by explaining gamification and its necessity, considering its potential to increase the effectiveness of achieving goals. Unlike the previous one, the author's research subject was elementary school students. The use of gamification has reinforced the perception of traditional learning as boring and ineffective, while improving communication and problem-solving skills. Despite this, the influence of parents on children and their motivation remain unchanged. Therefore, the authors decided to study the parents' opinion on gamification. The study

involved 16 students and their parents from the primary school of the Ministry of National Education of Northern Cyprus. Preliminary and post-test tests were used to assess the level of motivation, and interviews were conducted with parents and students to find out their opinions. The ClassDojo app was used to gamify science lessons. The app gave negative and positive marks depending on the students' skills, as well as assessed homework and provided feedback in the app. The students were divided into four groups. Based on the data obtained from the app, the group with the highest score received awards, and students were given the opportunity to change their avatar. After receiving the results, the Wilcoxon rank test method was used to analyze the motivation level. The effectiveness of gamification to increase motivation in science lessons was determined. Interviews with students and parents revealed positive feedback from both sides. The conclusion demonstrated the effectiveness of gamification in developing positive qualities of students (*ibid.*).

In the work of Angelilli (2023), the authors aim to use the heroes of Brazilian folklore to create a game that develops critical thinking and empowers vulnerable communities affected by misinformation and fake news. Four groups from the city of Goiania were selected for the study: one group was homeless, two groups were from urban and suburban areas, and one group was garbage collectors. It used the methodology of a role-playing game (RPG), in which the player assumes a new, distinctive role, different from his everyday persona. The host starts the game from the stage, and the players must decide together what to do next. After making a decision, the moderator displays the result, showing how it affected the course of the game. To understand the structure, the players were given cards with the characteristics of their characters. The results showed that the participants demonstrated a high level of game learning combined with creativity and critical thinking in real life. As the final conclusions have shown, game learning is effective for developing critical thinking not only in schoolchildren, but also in adult learners (*op cit.*).

In an article by Chávez Suárez et al. (2024), the goal was to evaluate the effectiveness of gamification in developing students' critical thinking in a math lesson.

Seventy-four 10th grade students enrolled in the Basic General Education (BGE) program at an educational institution in Quito were selected to participate in the study. Each game lesson lasted from two to three hours, and a total of 10 lessons were conducted offline. For a descriptive analysis, pre- and post-test tests were used to compare effectiveness. The games used in the lessons were adapted to the cognitive level of the students, and their difficulty level was gradually increased to develop analytical thinking and reasoning. The analysis of the pre- and post-test tests showed the effectiveness of gamification in the development of critical thinking. The study concludes that with good design and implementation, gamification will yield positive results, but problems include dependence on context and the need to avoid distractions (*ibid.*).

The article written by Ravil and Rinat Ramazanov (2025) is aimed at strengthening critical thinking and solving skills problems along with increasing engagement in learning using gamification. To achieve this goal, a 3-week Lesson Study was chosen, the participants were students of the 12 high school students of Nazarbayev Intellectual School in the age range of 15-16 years. The gamification elements in the study included challenge levels, personalized avatars, and group work. There was also a virtual assistant in gamified activities. Assistant helped with instructions, sent motivational messages, and used reflective prompts to increase efficiency, for example, by asking students to explain their logic. Group work with problem solving scenarios was chosen to enhance analytical abilities; after finishing special exercises, "knowledge crystals" were given. The mixed approach method was used for reflection and observation. A Likert scale was chosen to test motivation; engagement was shown through participation and completion of the task. The data obtained showed a positive effect of gamification, engagement and motivation were increased by the corresponding 15% and 0.9. Reasoned responses and teamwork during gamification showed an increase in solving skills problems along with independent learning and analytical thinking. This article proves the effectiveness of gamification by various indicators in the computer science class. Findings suggest the usage of

gamification as an approach in STEM education for increased learning outcomes.

Unlike other articles, the work written by Temirbay A. (2025) considers gamification in chemistry together with theoretical models as constructivism. This work is aimed at learning the concepts of Organic Chemistry in secondary school systematically and in long-term memorization through gamification. ChemPlay was chosen as the gamification element, this game includes flashcards, matching, and writing appropriate reactions. The authors suggest using this game to repeat the theme of Organic Chemistry. The game includes team activities of 4-5 students, teams will compete for the number of correct answers to questions within a minute. Correct answers will help you move to the top. The authors described several distinctive features of this game when used in chemistry, such as memorizing materials in long-term memory, increased student interest, the possibility of differentiation, and an emotionally positive reaction in the classroom.

Lutfi (2021) work was conducted as a case study in Indonesia, the authors aim to study the effectiveness of computer-assisted games as a learning environment for improving the quality of Chemistry education in high school. The study was conducted in three different classrooms at three different schools that were randomly selected. The total number of students was 88; 28 of them were the control group. Unlike other papers, there are 2 experimental groups, each with 30 students. The chosen topic for the study was called Atoms and Molecules. The collection of information began with a pre-test, followed by change of behavior during the introduction of gamification, ended with a post-test, and students also answered questionnaires. The lesson lasted 90 minutes. After the lesson, a post-test was conducted. The data obtained from the pre- and post-test shows a significant difference between the control group and the experimental group, the experimental group showed high results in training and engagement in the lesson. This computer game will help students to easily learn chemistry by attracting them through the choice of colors and content. The author mentioned that chemistry is a suitable subject for this type of research, but it would be better to try to conduct research in other subjects (Kamal, 2025).

Sahito (2024) conducted research on the topic with the aim of finding an effective tool for increased student engagement with enhanced critical thinking in STEM education. The main part of the study was gamification, which showed the relationship of gamified activities to motivation, critical thinking, and problem solving skills of students in STEM education. Quantitative and qualitative methods were used for evaluation, the first method examined the representation of participants before and after the implementation of gamification. The second method included an observation of the classroom, a survey, and an interview. This study includes 120 participants of 9-12 grades from three urban public high schools that teach Stem education. The schools were chosen based on the possibility of adapting to gamification and access to resources such as the Internet. Two teachers from each school, overall 6 teachers were trained to implement gamification to the lessons. The gamification elements were points, rewards, missions, group and individual work. The data for the analysis was collected using pre- and post-tests to determine the level of critical thinking and problem solving skills. The interview was semi - structured and collected from 20 students with 6 teachers. The collected data showed positive gamification traits for critical thinking and problem solving skills among high school students, despite demographic differences and grades (*op cit.*).

Abbassyakhrin's (2024) work includes a study of the effect of metacognitive skills and critical thinking in implementing gamification to high school Biology. This study was used in quasi-experimental research. The Gamification website and syllabus, along with the Learning Implementation Plan, were used as tools. Metacognitive abilities were tested using a test on a scale of 0-7, and critical thinking was tested using a test on a scale of 0-5 based on the critical thinking assessment rubrics. The participants in this training were 30 high school students from Bima City. The data was collected in the first semester of the 2021-2022 academic year in quantitative form as an estimate. Gamification website design includes navigation keys, which is continued by challenges of the appropriate level. After the end of the challenge, the result page is displayed, provided that you get the right number of correct answers. If you haven't

reached the indicated goal, then you need to switch again with a time limit. Random motivation windows appear while completing tasks. After reaching the goal, the participants will see the prizes received in the form of medals. The data obtained was analyzed, the results showed the possibility of using gamification to enhance megacognitive skills along with critical thinking (*ibid.*).

The literature has examined the scholarly evidence bearing the development of critical thinking through gamification in chemistry education, and the contribution of gamification to problem-solving in chemistry education and across different subjects. Across all thematic areas, the evidence consistently points toward gamification's capacity to transform the quality of chemistry learning, motivationally, cognitively, and behaviorally only when implemented with sufficient pedagogical sophistication, subject-matter alignment, and instructional duration.

The critical thinking literature demonstrates that gamification in chemistry education develops not merely the capacity for critical reasoning but the disposition to exercise it spontaneously in chemical problem contexts. It can be inferred from the problem-solving literature that gamification helps improve chemistry problem-solving in at least three different ways: directly by providing increasingly difficult problems to solve along with immediate feedback; indirectly by affecting motivational and metacognitive states; and structurally by promoting productive failure as well as viewing chemistry problems as real challenges requiring intellectual work.

Overall, based on the analysis of the literature presented above, it can be concluded that gamification plays two main roles in modern chemistry education: it helps to foster student motivation and engagement, and also leads to the development of cognitive skills in young people. The reviewed studies show that gamification can be effectively used in different educational contexts depending on specific circumstances and needs.

METHODOLOGY

2.1 Research Design

A sole research paradigm would not suffice in this case. The research questions which guide this research are varied; while some of the questions need quantifiable proof of any cognitive change, others depend upon an explanation of the experience of the students involved. This is where the rationale behind choosing mixed methods comes into play. Gamification cannot be tested only by looking at the scores obtained, neither can it be analyzed through mere qualitative analysis. Using mixed methods will help explore both dimensions simultaneously, leading to data collection through each dimension independently followed by integration in the next step.

Furthermore, this finding is reinforced by the nature of the academic discipline. Based on the results of the literature review, most of the previous studies that examined the phenomenon of gamification in teaching chemistry were done using a mixed-method approach. This finding conforms to the fact that the academic field has already addressed this methodology problem and found its proper conclusion.

The quantitative section uses a pre-test/post-test approach based on the tool designed by Chávez Suárez et al. (2024). The decision to use this tool was deliberate in that it was explicitly designed to measure knowledge learning in the field of chemistry while concurrently assessing higher order cognitive functions such as critical thinking and problem solving, and not viewing these aspects as separate entities. This tool has proven to be reliable and valid in previous studies, thus alleviating any uncertainty regarding the methodology of this study.

The instrument designed by Chávez Suárez et al. (2024) is different from a standard chemistry test in the sense that it does not resemble what a typical student would consider to be an assessment in chemistry. While a test may rely heavily on the recollection of information that students have previously learned, the new instrument encourages the learners to engage in activities that require more effort. For instance, students will be presented with real-life situations that involve analysis, evaluation, and synthesis of knowledge gained throughout their educational careers. Problem solving

plays a key role in the instrument's structure; it ensures that the instrument can move beyond declarative knowledge into procedural and strategic knowledge—the ability to apply knowledge in practice and respond in a time of need.

Two points in time were considered for the test: once before the game-based intervention started, when the level of knowledge and cognitive skills could be measured as a base value, and after it, to measure any differences. As the same technique is used both in the pre-test and post-test situations, the values are directly comparable. What is more important, no reliance was placed on students' subjective feelings on whether they learned anything or not.

Qualitative research, in turn, has its own logic of knowing. Specifically, qualitative interviews based on Hursen's (2019) template have been used to shed light on some of the aspects of the students' experience, namely, affective, motivational, and personal changes. While the former aims at finding evidence of cognitive changes through the use of test scores, the latter is interested in exploring the nature of cognitive change and the causes underlying it. Hursen's original questions, intended for gaining insight into the students' opinions about gamification in education, have been modified in accordance with the specifics of this study focused on high school chemistry. Thus, questions are adapted to the reality of the participants' experience of gamified chemistry class. As far as the method of semi-structured interview was chosen, its advantage lies in ensuring consistency of the questioning procedure while at the same time giving an opportunity for pursuing unexpected leads.

The interviews were conducted with a group of selected students following the implementation of the program. All the interviews were conducted in an encouraging environment. They were all taped for later transcription.

Semi-structured interview choice is based on the methodology proposed by Sahito (2024). According to Sahito, semi-structured interviews are particularly useful in educational research settings seeking to uncover complicated cognitive and affective processes. During the investigation into the gamification experience in STEM classes, it was found that semi-structured interviews provide an adequate balance between

structuring and flexibility of interviewing process. That way, consistency of answers is ensured along with room for further probing and discussion on the basis of individual reactions.

2.2 Sampling

There was only one principle driving the sampling process: if the influence of gamification is considered as a fact, it should be visible throughout education facilities that vary in characteristics that are most crucial for the research, such as resourcefulness, culture, previous academic achievements, and nature of the establishment itself. Therefore, for the purpose of this paper, three types of schools have been chosen: public gymnasium, lyceum, and private school. These are three different types of educational establishments providing their own unique understanding of gamification, which would otherwise be unattainable with the use of single-site approach. As a preliminary step before the experiment, a pilot study was conducted at a nearby private school. All of the necessary agreements with the administration of the relevant educational facilities were made after that.

In each educational institution, the pupils were divided into two subgroups, namely, control subgroup and experimental subgroup. In the control subgroup, pupils followed traditional teaching procedures, whereas in the experimental one, they used a gamification treatment. The sizes of both subgroups in each institution were the same, which had its methodological consequences. The total number of students was equal to 92 people, of whom there were 28 pupils in the public gymnasium, 14 in each group, 24 pupils in the lyceum, 12 in each group, and 40 pupils in the private school, 20 in each group.

Three educational organizations have been chosen owing to the distinctive nature of each institution, giving rise to the analytical relevance. In the case of the state-owned gymnasium, the institution operates under the normal conditions associated with state education. Conversely, the lyceum exists in another normative space. This institution tends to be selective in its academic admissions policy. Students attending the lyceum have high academic performance levels; thus, gamification will not be measured by

disengagement, but against the background of an already present tradition of academic rigor. Finally, the private institution is unique due to its higher economic potential and greater room for pedagogic innovation.

2.3 Data Collection

The test was given to both the control and experiment group students in three schools, before and after the program. The number of questions on the test was six in each section, which comprised equally critical thinking and problem solving. The marking scheme emphasized the cognitive difficulty level. Critical thinking questions were marked from five to 10 marks, apart from a 15-mark question; while problem solving questions were from 10 to 15 marks. It was done to ensure that the instrument rewarded not mere recall but the application of chemistry concepts to unfamiliar situations (Chávez Suárez et al., 2024). Pre- and post-tests questions are shown in the Appendix 1 section p. 71.

Because curricula diverged across schools, the testing instrument could not be standardized, it had to be rebuilt. Fourteen pre-test and fourteen post-test questions were constructed fresh for each school, yielding 28 questions in total. It was decided to use 4 gamified chemistry lessons between pre- and post-tests to check change in critical thinking and problem-solving skills. Intervention of gamification for each school took from 2 weeks to 1 month based on the numbers of chemistry lessons in per week. In the private school and public gymnasium, meeting twice weekly, completed full cycle in two weeks; the lyceum, meeting once weekly, required a full month. 10 grade students at the lyceum and private school, 11 grade students at the gymnasium classes were chosen to do given study. Participants for groups were not chosen randomly, because there was no opportunity to randomly divide students.

The first two games ran on digital platforms fully, specifically Worldwall, Wordize and Baamboozle. Given games worked together for immediate scoring feedback, animations, and competitive mechanics kept the task legible to students without reducing it to entertainment. In the first game called ‘Bingo!’ Wordize and Worldwall platforms were used, in the game itself there were answers to questions

given. In the second game called ‘Baamboozle’, were open questions based on the themes. The third and fourth games inverted the dynamic entirely, because students built the materials themselves, constructing molecular models, designing posters around the given theme and writing problem-solving scenarios in quest to find key. All the problems in the named games used Canva to provide game conditions as a presentation. Named games were combined as hand-made games, that produces changes that virtual games cannot. Games made students negotiate objects, revise and defend them in front of others. In caused the change in the direction of cognitive labor of chemistry lessons, because level of games changed from easier to harder levels to foster critical thinking and problem-solving skills. All the games used during study were combined as a Manual, QR code to it shown in the Appendix 2 section p. 80. Manual itself contains all 16 games, including the ones used in the pilot study, for different chemistry subject themes for 10-11 grade students, it combines to 4 types of games.

All games were collected through the **leaderboard system**. The leaderboard system was not a fifth game, it acted as a spine that connected the other four. Points earned in all the activities were tallied for the whole group, whose overall score would determine its ranking. There were prizes to be won depending on the ranking, making each round significant. The nature of this point tallying process ensured that efforts had to be sustained because a bad showing in one round could not be compensated for by lack of effort in another round. More importantly, it created a conflict between competitiveness and cooperation.

The results of the quantitative research show what achievements students made, whereas the interviews were conducted to understand the reasons behind such results. In other words, semi-structured interview questions were formulated taking into account chemistry education and related issues about the effect of gamification on students’ critical thinking and problem-solving readiness, ways of their teamwork, etc.

In all, sixteen students participated in the interviews after the intervention with each experimental group being represented by equal numbers of respondents. Each

school participants were chosen 1/3 of experimental group for semi-structured interviews. For instance, a sampling frame with representation of diversity was used in selecting the participants for interviews based on their academic performance, gender, and engagement levels. In this regard, four respondents from lyceum, five from the public gymnasium, and seven from the private school took part in semi-structured interviews where eight questions were asked from each respondent.

2.3.1 Validity of Pre- and Post-tests, Semi-structured Interview Questions

This section gives information about the validity of pre- and post-tests as well as semi-structured interview questions used in private school, lyceums, and public gymnasium. The validity of the instruments that are used to collect data was checked independently from each other to provide trustworthy information separately. This independent validation approach ensures that the integrity of each instrument is assessed on its own merits, minimizing the risk of cross-instrument bias and strengthening the overall credibility of the data collection process.

Table 2.3.1.1. Validity of the Pre-test questions

Test Statistics	
N	4
Kendall's W ^a	,812
Chi-Square	42,214
df	13
Asymp. Sig.	<,001

a. Kendall's Coefficient of Concordance

Validity of the pre-test in Table 2.3.1.1 was evaluated using Kendall's W (Coefficient of Concordance) provided by SPSS software based on the ranking of 14 test items by four experts. According to this, it can be said that there is a high degree of concordance among all experts ($W = 0.812$). This result demonstrates that the experts consistently agreed on the relative importance and relevance of the test items, thereby supporting the content validity of the instrument. Items ranks are shown in the Appendix 3 section in p. 81. As shown in the table, Q5, Q8, Q13, Q14 have higher

mean ranks than Q2, Q3, Q6, Q9, Q10. Notably, all 14 items were retained following the expert review, as the differential in mean ranks reflected gradations in perceived centrality rather than any failure to meet the validity threshold, confirming that the instrument provides comprehensive coverage of the targeted learning outcomes. Overall, the findings indicate that the pre-test possesses strong validity, making it suitable for use in given research. This level of expert agreement further strengthens the trustworthiness of subsequent findings drawn from pre-test results across all three school sites.

Table 2.3.1.2. Validity of the Post-test Questions

Test Statistics	
N	4
Kendall's W^a	,802
Chi-Square	41,715
df	13
Asymp. Sig.	<,001

a. Kendall's Coefficient of Concordance

The validity of post-test in Table 2.3.1.2 was evaluated using Kendall's Coefficient of Concordance (W) from the SPSS software based on expert rankings of 14 items. Results demonstrated a high level of consensus among the four experts ($W = 0.802$), which was statistically significant. This indicates that experts consistently agreed on the relative importance and relevance of the test, thereby supporting the content validity of the instrument. Items ranks are shown in the Appendix 3 section in p. 81. As shown in the table, Q1, Q3, Q4, Q6, Q10, Q14 have higher mean ranks than Q2, Q5, Q9, Q13. Notably, all 14 items were retained following the expert review, as the differential in mean ranks reflected gradations in perceived centrality rather than any failure to meet the validity threshold, confirming that the instrument provides comprehensive coverage of the targeted learning outcomes. Overall, the findings indicate that the post-test possesses strong validity, making it suitable for application

in the study. This level of expert agreement further strengthens the trustworthiness of subsequent findings drawn from post-test results across all three school sites.

Table 2.3.1.3. Validity of Semi-structured Interview Questions

Test Statistics	
N	4
Kendall's W^a	,841
Chi-Square	23,545
df	7
Asymp. Sig.	,001

a. Kendall's Coefficient of Concordance

Validity of semi-structured interview questions in Table 2.3.1.3 was established using Kendall's Coefficient of Concordance (W) as measured using SPSS based on ranking of eight questions by four experts. It has been found that there is an extremely high degree of agreement between the four experts concerning the importance and relevance of the interview questions since W equals 0.841. This indicates that the experts have similar views about the relevance of the items. The ranking of the items is shown in Appendix 3 section in p. 81. From the data presented in the table, it can be observed that Q1, Q3, Q5, Q6, Q7, and Q8 have relatively higher mean ranks compared to Q2. Notably, all 8 items were retained following the expert review, as the differential in mean ranks reflected gradations in perceived centrality rather than any failure to meet the validity threshold, confirming that the instrument provides comprehensive coverage of the targeted learning outcomes. This shows that the semi-structured interview questions have extremely high validity. This level of expert agreement further strengthens the trustworthiness of subsequent findings drawn from semi-structured interview results across all three school sites.

2.3.2 Reliability of Pre- and Post-tests Results

Internal consistency reliability for both the pre-test and post-test was assessed using McDonald's omega coefficient, computed in Jamovi, with a threshold of $\omega \geq 0.70$ adopted as the minimum acceptable level of reliability in accordance with widely cited

conventions in educational measurement research. The reliability of the combined pre- and post-test instrument was examined across three school contexts - a private school, a lyceum, and a public gymnasium. These reliability estimates complement the content validity evidence reported in the preceding section, collectively establishing that the instruments were both theoretically grounded and internally consistent prior to administration across all three school sites. The omega coefficients obtained across all three school contexts confirm that the instruments demonstrated adequate internal consistency, supporting their suitability for generating dependable data from which valid comparisons and conclusions may be drawn.

Table 2.3.2.1. Reliability of Private school's Pre- and Post-tests Results

	Mean	SD	McDonald's ω
scale	10.8	7.05	0.713

Internal consistency of the measures of pre- and post-tests at the private school has been tested with McDonald's omega (ω) in Table 2.3.2.1. This test statistic was computed through Jamovi. In this respect, the outcome revealed $\omega = 0.713$. The result exceeded the standard minimum level of 0.70; hence, one can state the acceptable level of internal consistency of the measures. Additionally, the mean value of 10.8 with SD = 7.05 denotes acceptable variability in the answers provided by the learners. Overall, it may be said that the tests have been reliably used.

Table 2.3.2.2. Reliability of Lyceum's Pre- and Post-tests Results

	Mean	SD	McDonald's ω
scale	19.0	7.28	0.760

The reliability of pre- and post-test scores at the lyceum has been estimated using McDonald's ω with Jamovi software, data shows $\omega = 0.760$. This Table 2.3.2.2 implies that there is high internal consistency among the items of the tool. Also, the average score of 19.0 (SD = 7.28) reflects that the students' scores exhibit sufficient variance, hence demonstrating the discriminative nature of the test. Taken together, all the

information proves the reliability of the tests used in this study for lyceum's sample, also its results will be reliable enough to be interpreted to answer research questions using information from it.

Table 2.3.2.3. Reliability of Public gymnasium's Pre- and Post-tests Results

	Mean	SD	McDonald's ω
scale	23.0	4.05	0.718

Reliability of the pre-and-post test scores in public gymnasium is shown at the Table 2.3.2.3, it has been measured through McDonald's ω in Jamovi and found to be at the level of $\omega = 0.718$. The measure is above the accepted standard of $\omega > 0.70$. Thus, the internal consistency reliability of the test is satisfactory. Moreover, an average of 23.0 (with SD = 4.05) reveals good performance levels with little variation in response patterns. These findings confirm that the pre- and post-test measures are reliable for evaluating the targeted skills within the lyceum sample.

2.4 Data Analysis

Prior to conducting the main statistical analyses, the assumptions of normality and homogeneity of variance were examined for post-test scores across all three school types - private school, lyceum, and public gymnasium - for both critical thinking and problem-solving skills. Normality was assessed using the Shapiro-Wilk test, which is considered the most appropriate test for normality in studies with relatively small sample sizes, as it demonstrates greater statistical power compared to other normality tests. Homogeneity of variance was evaluated using Levene's test, which examines whether the variances of the compared groups are statistically equal. The assumption checks were conducted separately for each school type and for each skill domain to ensure precision and accuracy in the selection of subsequent statistical procedures. The results indicated that the assumption of normality was violated in several groups across the three school settings, with some distributions departing significantly from normality as evidenced by statistically significant Shapiro-Wilk values ($p < 0.05$). Similarly, the assumption of homogeneity of variance was not consistently met across

all comparison groups. These findings collectively suggested that the conditions required for parametric testing were not sufficiently satisfied, necessitating the use of a non-parametric alternative for the subsequent comparative analyses between the experimental and control groups.

2.4.1 Analysis of Critical thinking skill

The assumptions of normality and homogeneity of variances were examined prior to selecting the appropriate statistical test in the Jamovi software. The Shapiro-Wilk test for normality and Levene's test for homogeneity of variance were conducted across all four groups - the private school, lyceum, public gymnasium, and the combined sample named all schools. In all cases, the resulting p-values fell below the 0.05 significance threshold, indicating that data did not meet the parametric assumptions of normal distribution and equal variances. Given the data across all groups was determined to be non-parametric in nature, the Mann-Whitney U Test was selected as the most appropriate analytical approach for examining differences between critical thinking and problem-solving skills between the groups. Tables themselves are shown in the Appendix 4 section p. 82.

2.4.2 Analysis of Problem-solving skill

The assumptions of normality and homogeneity of variances were similarly examined before determining the appropriate statistical test for problem-solving skills in the Jamovi software. Shapiro-Wil and Levene's tests were applied across the private school, lyceum, public gymnasium, and the overall combined sample with the name all schools. The p-values obtained for all four groups were below the 0.05 significance level, indicating a violation of the normality and homogeneity assumptions required for parametric testing. As the data across all groups demonstrated non-parametric characteristics, the Mann-Whitney U Test was consequently chosen as the most suitable method for analyzing differences in problem-solving skills between the groups. Tables were placed in the Appendix 5 section p. 84.

2.4.3 Thematic Analysis of Semi-structured Interview

The analysis employed Braun and Clarke's six-step process. Initially, familiarization was carried out through several readings of the entire dataset, consisting of all 16 interview transcripts, after which initial codes were generated using key words and themes that emerged from each answer. These codes were then grouped together to form potential themes within the data set and examined in the light of both the coded data and the entire data set. Each theme was then identified and labeled, thus providing the current analysis (Ahmed et al., 2025). In order to preserve the order in which the questions were asked in the interview, coding was done per question and not for the entire interview; each answer was coded individually before grouping them together. The participants' numbers (P1-P16) have been kept throughout to maintain transparency. "Prevalence figures" refer to the percentage of participants whose answers were coded within a particular theme. These should not be seen as statistics but merely as an indication. The questions asked and their corresponding answers from the interviews are provided in Appendix 6 section, in p. 86.

RESULTS

This section shows results collected from post-tests for each school and semi-structured interview. Results presented below are based on the the Mann-Whitney U Test, while the second table for each school reflects descriptive statistics derived from post-test scores, used to illustrate the differences between the control and experimental groups. Qualitative findings drawn from semi-structured interviews are integrated alongside the quantitative results to provide a comprehensive account of the observed outcomes.

3.1 Result of Critical thinking skill (RQ1)

Given subsection answers to the Research Question 1 and shows results of the critical thinking skill level differences between control and experimental group in private school, lyceum, public gymnasium and across all school's combined sample. All informations used to draw conclusion based on improvement in critical thinking scores between the experimental and control groups.

3.1.1 Results of Critical thinking skill in Private school's sample

Table 3.1.1.1. Group Descriptives. Critical thinking skill

	Group	N	Mean	Median	SD	SE
Post-test.CT	C	20	23.5	25.0	6.90	1.54
	E	20	29.0	30.0	2.05	0.459

For the private school sample, descriptive statistics from the Jamovi software in Table 3.1.1.1 were calculated to compare the control and experimental groups on post-test critical thinking skill scores. The control group ($n = 20$) obtained a mean score of 23.5 ($SD = 6.90$), with a median of 25.0. The experimental group ($n = 20$) achieved a higher mean score of 29.0 ($SD = 2.05$), with a median of 30.0. The notably higher mean and median scores of the experimental group, combined with the smaller standard deviation, suggest not only superior performance but also greater consistency among students who received the gamified intervention.

Table 3.1.1.2. Mann Whitney U Test. Critical thinking skill

		Statistic	p	Mean difference
Pre-test.CT	Mann-Whitney U	90.0	0.002	-5.00
Post-test.CT	Mann-Whitney U	84.0	<.001	-5.00

For the private school sample, a Mann-Whitney U Test analysis was conducted to determine whether there were mean differences in pre- and post-tests critical thinking skill scores between the control and experimental groups in the Jamovi software. In Table 3.1.1.2 in the private school sample, the experimental group consistently outperformed the control group in critical thinking by approximately 5 points. At pre-test, this difference was already statistically significant ($U = 90.0$, $p = 0.002$). At post-test, the same mean difference persisted (-5.00), but with stronger statistical evidence ($U = 84.0$, $p < 0.001$). These results suggest that while gamification reinforced the experimental group's advantage, the observed effect must be interpreted cautiously given the baseline imbalance.

3.1.2 Results of Critical thinking skill in Lyceum's sample

Table 3.1.2.1. Group Descriptives. Critical thinking skill

	Group	N	Mean	Median	SD	SE
Post-test.CT	E	12	24.6	25.0	6.56	1.89
	C	12	15.4	20.0	10.5	3.04

For the lyceum sample, descriptive statistics from the Jamovi software in Table 3.1.2.1 were calculated to compare the experimental and control groups on post-test critical thinking skill performance. The experimental group ($n = 12$) obtained a mean score of 24.6 ($SD = 6.56$), with a median of 25.0. In contrast, the control group ($n = 12$) achieved a lower mean score of 15.4 ($SD = 10.5$), with a median of 20.0 from the post-test. The notably higher mean and median scores of the experimental group, combined with the smaller standard deviation, suggest not only superior performance but also greater consistency among students who received the gamified intervention.

Table 3.1.2.2. Mann-Whitney U Test. Critical thinking skill

		Statistic	p	Mean difference
Pre-test.CT	Mann-Whitney U	57.5	0.393	-1.51
Post-test.CT	Mann-Whitney U	32.0	0.019	-5.00

To determine whether the intervention produced differences in pre- and post-tests critical thinking skill scores between the experimental and control groups in the lyceum, a Mann-Whitney U Test was conducted. The analysis from the Jamovi software shown in Table 3.1.2.2. In the lyceum sample, the control and experimental groups did not differ at pre-test ($U = 57.5$, $p = 0.393$), with a mean difference close to zero. At post-test, however, the experimental group scored significantly higher than the control group ($U = 32.0$, $p = 0.019$), with a mean difference of -5.00 . This shift from equivalence to significant divergence suggests that gamification strategies effectively enhanced students' critical thinking skills compared to traditional instruction. The pre-test equivalence between groups strengthens the internal validity of these findings, as any observed post-test differences can be more confidently attributed to the intervention rather than pre-existing ability differences.

3.1.3 Results of Critical thinking skill in Public gymnasium's sample

Table 3.1.3.1. Group Descriptives. Critical thinking skill

	Group	N	Mean	Median	SD	SE
Post-test.CT	E	14	28.2	30.0	2.49	0.664
	C	14	23.2	22.5	4.64	1.24

For the gymnasium sample, descriptive statistics from the Jamovi software in Table 3.1.3.1 were calculated to compare the experimental and control groups on post-test critical thinking skill performance. The experimental group ($n = 14$) obtained a mean score of 28.2 ($SD = 2.49$), with a median of 30.0. In contrast, the control group ($n = 14$) achieved a lower mean score of 23.2 ($SD = 4.64$), with a median of 22.5. The notably higher mean and median scores of the experimental group, combined with the

smaller standard deviation, suggest not only superior performance but also greater consistency among students who received the gamified intervention.

Table 3.1.3.2. Mann-Whitney U Test. Critical thinking skill

		Statistic	p	Mean difference
Pre-test.CT	Mann-Whitney U	86.0	0.588	1.79
Post-test.CT	Mann-Whitney U	38.5	0.004	-5.00

From looking at violations on normality and homogeneity, the Mann-Whitney U Test was employed as a non-parametric alternative in the Jamovi software. To get better results and analysis for critical thinking skill, mean differences of pre- and post-tests scores of Public gymnasium's sample was compared in Table 3.1.3.2. In this sample, the control and experimental groups did not differ at pre-test ($U = 86.0$, $p = 0.588$), with a mean difference close to zero. At post-test, however, the experimental group scored significantly higher than the control group ($U = 38.5$, $p = 0.004$), with a mean difference of -5.00 . This shift from close to zero point to -5.00 suggests that gamification strategies effectively enhanced students' critical thinking skill compared to traditional instruction, providing strong evidence of the intervention's impact since the groups were initially balanced. The pre-test equivalence between groups strengthens the internal validity of these findings, as any observed post-test differences can be more confidently attributed to the intervention rather than pre-existing ability differences.

3.1.4 Results of Critical thinking skill in All school's sample

Table 3.1.4.1. Group Descriptives. Critical thinking skill

	Group	N	Mean	Median	SD	SE
Post-test.CT	E	46	27.6	30.0	4.18	0.617
	C	46	21.3	22.5	8.13	1.20

In group descriptives from the Jamovi software in Table 3.1.4.1 by critical thinking skill from results combined across all schools. As shown from the table, the

experimental group (n = 46) obtained a mean score of 27.6 (SD = 4.18), with a median of 30.0. In contrast, the control group participants results across all schools (n = 46) achieved a lower mean score than experimental group, showing 21.3 (SD = 8.13), with a median of 22.5. The notably higher mean and median scores of the experimental group, combined with the smaller standard deviation, suggest not only superior performance but also greater consistency among students who received the gamified intervention.

Table 3.1.4.2. Mann-Whitney U Test. Critical thinking skill

		Statistic	p	Mean difference
Pre-test.CT	Mann-Whitney U	917	0.263	-1.73
Post-test. CT	Mann-Whitney U	475	<.001	-5.00

To evaluate differences in pre- and post-tests critical thinking skill scores between the experimental and control groups across all schools, the Mann-Whitney U Test analysis was conducted in Jamovi software. To get better results and analysis for critical thinking skill, mean differences of pre- and post-tests scores of All school's sample was compared in Table 3.1.4.2. In this sample, the control and experimental groups did not differ at pre-test ($U = 917$, $p = 0.263$), with a mean difference close to zero. At post-test, however, the experimental group scored significantly higher than the control group ($U = 475$, $p < 0.001$), with a mean difference of -5.00 . This shift from close to zero to -5.00 suggests that gamification strategies effectively enhanced students' critical thinking skill compared to traditional instruction, providing strong evidence of the intervention's impact since the groups were initially balanced.

3.2 Results of Problem-solving skill (RQ2)

Given subsection answers to the Research Question 2 and shows results of the problem-solving skill level differences between control and experimental group in private school, lyceum, public gymnasium and across all school's combined sample.

3.2.1 Results of Problem-solving skill in Private school's sample

Table 3.2.1.1. Group Descriptives. Problem-solving skill

	Group	N	Mean	Median	SD	SE
Post-test. PS	C	20	17.5	22.0	11.5	2.58
	E	20	37.5	35.0	7.16	1.60

For the private school sample, descriptive statistics from the Jamovi software in Table 3.2.1.1 were calculated to compare the control and experimental groups on post-test problem-solving skill performance. The control group ($n = 20$) obtained a mean score of 17.5 ($SD = 11.5$), with a median of 22.0. In contrast, the experimental group ($n = 20$) achieved a higher mean score of 37.5 ($SD = 11.5$), with a median of 35.0. The notably higher mean and median scores of the experimental group, combined with the smaller standard deviation, suggest not only superior performance but also greater consistency among students who received the gamified intervention.

Table 3.2.1.2. Mann-Whitney U Test. Problem-solving skill

		Statistic	p	Mean difference
Pre-test. PS	Mann-Whitney U	142.0	0.105	-5.00
Post-test. PS	Mann-Whitney U	17.5	<.001	-20.00

To assess differences in pre- and post-tests problem-solving skill scores between the control and experimental groups, a Mann-Whitney U Test was conducted. To get better results and analysis for problem-solving skill for Private school's sample, mean differences of pre- and post-tests scores was compared in Table 3.2.1.2. In this sample, the control and experimental groups did not differ significantly at pre-test ($U = 142.0$, $p = .105$), with a mean difference of -5.00 . At post-test, however, the experimental group scored significantly higher than the control group ($U = 17.5$, $p < .001$), with a mean difference of -20.00 . This shift from -5.00 to -20.00 suggests that gamification strategies effectively enhanced students' problem-solving skill compared to traditional instruction.

3.2.2 Results of Problem-solving skill in Lyceum's sample

Table 3.2.2.1. Group Descriptives. Problem-solving skill

	Group	N	Mean	Median	SD	SE
Post-test. PS	E	12	40.8	45.0	5.15	1.49
	C	12	30.0	30.0	4.26	1.23

For the lyceum sample, descriptive statistics from the Jamovi software, in Table 3.2.2.1 were calculated to compare the experimental and control groups on post-test problem-solving skill performance. The experimental group ($n = 12$) obtained a mean score of 40.8 ($SD = 5.15$), with a median of 45.0. In contrast, the control group ($n = 12$) achieved a lower mean score of 30.0 ($SD = 4.26$), with a median of 30.0. The notably higher mean and median scores of the experimental group, combined with the smaller standard deviation, suggest not only superior performance but also greater consistency among students who received the gamified intervention.

Table 3.2.2.2. Mann-Whitney U Test. Problem-solving skill

		Statistic	p	Mean difference
Pre-test. PS	Mann-Whitney U	72.00	1.000	0.0
Post-test. PS	Mann-Whitney U	7.50	<.001	-10.0

Both assumptions, the normality and homogeneity were not met, the Mann-Whitney U Test was applied as a non-parametric alternative to the analysis in Jamovi software. To get better results and analysis for problem-solving skill, mean differences of pre- and post-tests scores of Lyceum's sample was compared in Table 3.2.2.2. In this sample, the control and experimental groups did not differ at pre-test ($U = 72.0$, $p = 1.000$), with a mean difference of 0.0, confirming baseline equivalence. At post-test, however, the experimental group scored significantly higher than the control group ($U = 7.5$, $p < .001$), with a mean difference of -10.0 . This shift from 0.0 to -10.00 suggests that gamification strategies effectively enhanced students' problem-solving skill compared to traditional instruction, providing strong evidence of the intervention's

impact since the groups were initially balanced. The pre-test equivalence between groups strengthens the internal validity of these findings, as any observed post-test differences can be more confidently attributed to the intervention rather than pre-existing ability differences.

3.2.3 Results of Problem-solving skill in Public gymnasium's sample

Table 3.2.3.1. Group Descriptives. Problem-solving skill

	Group	N	Mean	Median	SD	SE
Post-test. PS	E	14	40.7	45.0	5.14	1.37
	C	14	33.6	35.0	4.13	1.10

The experimental group (n = 14) in post-test looking at problem-solving skills from the Jamovi software, in descriptives in Table 3.2.3.2 obtained a mean score of 40.7 (SD = 5.14), with a median of 45.0. In contrast, the control group (n = 14) achieved a lower mean score of 33.6 (SD = 4.13), with a median of 35.0 than experimental group. Table 3.2.3.1 showed differences between scores of control and experimental groups in public gymnasium. The gap of approximately 7 points between the mean scores of the two groups, alongside the higher median of the experimental group, reflects a meaningful difference in problem-solving skill performance attributable to the gamified intervention delivered in the public gymnasium setting. Additionally, the slightly larger standard deviation in the experimental group (SD = 5.14) compared to the control group (SD = 4.13) suggests that while the intervention consistently elevated performance, individual responses to the gamified activities varied to a modest degree among students.

Table 3.2.3.2. Mann-Whitney U Test. Problem-solving skill

		Statistic	p	Mean difference
Pre-test. PS	Mann-Whitney U	91.5	0.767	3.83
Post-test. PS	Mann-Whitney U	31.0	<.001	-10.00

Both assumptions of normality and homogeneity were not met, the Mann-Whitney U Test was applied as a non-parametric alternative in Jamovi software. To get better results and analysis of problem-solving skill for Public gymnasium's sample, mean differences of pre- and post-tests scores was compared in Table 3.2.3.2. In this sample, the control and experimental groups did not differ at pre-test ($U = 91.5$, $p = .767$), with a mean difference close to zero. At post-test, however, the experimental group scored significantly higher than the control group ($U = 31.0$, $p < .001$), with a mean difference of -10.00 . This shift from equivalence to significant divergence suggests that gamification strategies effectively enhanced students' problem-solving skills compared to traditional instruction. The pre-test equivalence between groups strengthens the internal validity of these findings, as any observed post-test differences can be more confidently attributed to the intervention rather than pre-existing ability differences.

3.2.4 Results of Problem-solving skill in All school's sample

Table 3.2.4.1. Group Descriptives. Problem-solving skill

	Group	N	Mean	Median	SD	SE
Post-test. PS	E	46	39.3	40.0	6.20	0.914
	C	46	25.7	30.0	10.9	1.61

Across all schools, descriptive statistics from the Jamovi software, in Table 3.2.4.1 were calculated to compare the experimental and control groups on post-test problem-solving skill performance. The experimental group ($n = 46$) obtained a mean score of 39.3 ($SD = 6.20$), with a median of 40.0. In contrast, the control group ($n = 46$) achieved a lower mean score of 25.7 ($SD = 10.9$), with a median of 30.0.

Table 3.2.4.2. Mann-Whitney U Test. Problem-solving skill

		Statistic	p	Mean difference
Pre-test. PS	Mann-Whitney U	904	0.219	-1.09
Post-test. PS	Mann-Whitney U	221	<.001	-15.0

The table from the Jamovi software shows analysis of problem-solving skill scores between all schools. Because both assumptions were not met, the Mann-Whitney U Test was employed as a non-parametric alternative. To get better results and analysis for All school's sample, mean differences of pre- and post-tests scores was compared in Table 3.2.4.2. In this sample, the control and experimental groups did not differ at pre-test ($U = 904$, $p = .219$), with a mean difference close to zero. At post-test, however, the experimental group scored significantly higher than the control group ($U = 221$, $p < .001$), with a mean difference of -15.0 . This shift from equivalence to significant divergence suggests that gamification strategies substantially enhanced students' problem-solving skills compared to traditional instruction.

3.3 Results of Thematic analysis of semi-structured interview (RQ3 & RQ4)

Given subsection answers to the Research Question 3 & Research Question 4, and provides information about thematic analysis collected from 16 participants during semi-structured interviews in all schools. It helps to understand how gamification affects students during chemistry education in high school without looking to students achievements, gender, or school type, and giving diverse information.

Question 1. Enjoyment of the Chemistry Education Classes

The first question posed in the interview focused on the participants' level of enjoyment with regard to the chemistry education classes that were provided in a gamified format. It turned out that each of the 16 participants in the sample had a clearly positive attitude towards the classes mentioned above.

Two main themes stood out in the coded responses. First, there was the theme of Universal affective acceptance, which refers to the simple affirmative responses that were found throughout the whole sample. Some examples included statements like "Yes" (P12, P8, P12), and "Yes, I am interested" (P11). Second, there was the theme of Intrinsic enjoyment and emotional engagement, which referred to statements showing a more profound level of engagement than merely being obedient. Examples include

P1 saying the activity was enjoyable, while P16 mentioned liking team-oriented assignments specifically.

Question 2. Class Activities Perception

This question required the respondents to analyze the class activities themselves, evaluating the positives and negatives. The answers had a clear common trend consisting of a group of positive views on the activities, along with some few neutral or poorly explained views.

The main theme observed was Motivational engagement by novelty, with contributions being made by 87% of the sample size ($n = 14$). In all the participant contributions analyzed, the use of motivational and novel terms was common. Participant P9 stressed that the activity was “new,” highlighting novelty as one of the key motivators. Participant P8 expressed satisfaction with “games” and “enjoying lessons,” whereas Participant P10’s response, which included “Yes, I do,” signified that, for some participants, a good assessment required no explanation. P5 mentioned that the exercises were “motivating” to me,” thus emphasizing not the gamified features themselves, which were just part of the learning experience, but rather the role they played as factors that inspired me to learn actively.

In addition, there was one more minor theme that appeared from comments made by two subjects (13%); they could be characterized as showing neutral attitudes.

Question 3. Participant Reflections Regarding the Course

In relation to participant reflections about the overall evaluation of the course, two major themes emerged, showing the difference between deep affective participation and shallow cognitive evaluation.

Gamification as a Means of Course Enhancement is the dominant theme which was highlighted by thirteen participants (81%) in their answers. Participants viewed the course as being “engaging,” “interesting,” or “enjoyable.” Their responses act as evaluative descriptors, which give more significance than merely an expression of satisfaction because they indicate that gamification changed the nature of the course experience. For instance, participant P6 says “I love it”; participant P5 finds the course

"enjoyable"; while participant P13 associates the course with engagement because of the chance it provides to connect socially with others. Thus, the repetition of relational terms and expressions in this theme indicates that gamification is not just a teaching approach but rather a means of restructuring the whole experience of the course through student participation.

Theme 2 refers to the responses of three learners (19%) in regards to the neutral or surface level portrayal, whereby these students portrayed the learning process mainly in terms of functions or cognition, and referred to the process as "easy" (P7), "specific," and "fast" (P11). Even though their perceptions were not negative towards the process, these learners were unable to display any emotions regarding the process similar to those exhibited by the majority.

Question 4. Previous Experience with Gamification

Question 4 sought to determine participants' previous experience with gamification, finding a significant split that would help define the role of the course in introducing the idea.

Previous experience with gamification was stated by 11 respondents (69%). The level of familiarity with gamification among students was very different from one another: respondents like P1 ("Yeah, I knew more basics") and P13 ("Yeah, I knew about it") have some theoretical knowledge while students like P4 ("I heard about it") and P8 ("Yes") seem to have a general idea but no previous practical experience in gamifying their education. This difference within the theme is important to mention since some students never applied the method before taking part in the course.

Theme two, Gamification as a new term, showed up in five cases (31%), with participants P10 (No), P11 (Not sure), and P3 (No) having little or no familiarity with the term.

Question 5. Views about Applications of Gamification

The views that the participants had towards gamification in education appeared generally positive, albeit tempered by certain realities. Gamification as Motivation and Cognitive Stimulus Theme – 12 participants (75%) provided feedback on Gamification

as a motivator and cognitive stimulator, which was seen as an intrinsically motivating process, one which could enhance creativity and expand intellectual involvement. According to participant P16, Gamification was a way of making the “mind flexible,” which is a pertinent image which views Gamification as a source of cognitive flexibility. Participant P9 saw it as a medium through which the artistically inclined talent for chemistry was harnessed, thus showing that Gamification can serve as an intermediary to bridge different disciplines and allow a skill set acquired in one area be used in another.

Theme number two is that of Acknowledged practical limitations, which came up in four responses (25%). According to participant P2, gamification can be difficult to apply to themes. P8 expressed worries about the pressures of time management and the possibility that competition within groups might put individuals at a disadvantage if they cannot finish tasks according to deadlines.

Question 6. Self-perceived Strengths and Weaknesses

In Question 6, respondents were asked to comment on both the advantages and disadvantages of gamification. The answers given to this question proved to be the most complex analytically because, contrary to expectations, the two concepts are not contradictory; rather, some respondents mentioned both types of advantages and disadvantages in one answer, which explains why percentages do not add up to 100%.

The theme of Pedagogical and Relational Benefits of Gamification was noted in 13 answers (81%). Several advantages were stressed, such as motivation and engagement (P1, P14), active participation (P3), creativity (P6, P10), healthy teacher-student relationship (P4), and enhanced confidence (P12). One significant advantage of gamification is its relational dimension; gamification thus occurs not only at an individual cognitive level but also on a wider scale through interactions within the classroom culture and society. The point made by P12 about the potential of gamification “in terms of confidence and differentiation in lessons” shows this potential for more inclusive classrooms.

Secondly, implementation and feasibility issues were identified among responses (7 cases or 44%). Most often, respondents mentioned the burden of preparation faced by teachers: P16 expressed his doubts regarding teachers being able to prepare all of them, while P8 was afraid that because of time pressure, not all groups would manage to finish activities within the lesson period. Technical issues like devices' malfunctioning and lack of reliable internet connection were brought to light by P10. Finally, P13 presented a long-term issue, as he noted that once accustomed to game-based learning methods, students may find it difficult to return to conventional studying, which is a matter of serious concern for future curricula development.

Both strengths and weaknesses in single responses should be analyzed carefully.

Question 7. Emotional Reactions evoked through Gamification Techniques

Question 7 asked the respondents to describe their emotions experienced during the gamification of learning chemistry. This question provided the most variation in terms of the affective responses obtained from all interviews because the respondents used an extensive vocabulary to describe their positive emotions.

Engagement with positive emotions was evident in 15 out of 16 cases (94%), which stands as the most common single result among all of the observations. These mentioned emotions include motivation (P1, P14), joy (P9), excitement (P10), competitiveness (P5), and being ready (P11). Such a variety of positive results is worth noting. The emotions evoked as a result of gamification are diverse and indicate a true connection of people with various aspects of the gamification process. Particularly, it should be highlighted that the case of envy expressed by P16 because of groups reaching the first place is very important. The constructive role of competitive envy within gamified settings merits further theoretical attention in the wider gamification literature.

A single participant (P15) reported feeling 'relaxation', coded under the minority theme Neutral of muted emotional response. While relaxation is not in itself a negative outcome, its inclusion in this theme reflects the absence of the heightened affective engagement that characterized the majority. It is plausible that this participant

experienced the gamified format as low-stress and comfortable, an outcome of genuine value for learners prone to academic anxiety, even if distinct from the motivational arousal reported by peers.

Question 8. Types of Games Favored

The final qualitative question asked participants to name their preferred game format from those used throughout the course. Analysis produced two complementary themes that together shed light on the role of variety in sustaining engagement across a diverse learner group.

The theme differentiated format preferences reflects the spread of participant choices. The Baamboozle game received five responses (31%) from the participants, making it the highest choice among all options. Participant P14 pointed out that they found “random boxes” attractive because the element of surprise and the aspect of chance can sustain attention levels and prevent habituation which may otherwise result in reduced interest level. Participant P7 said that “we won it,” suggesting that winning is partially affected by their own preferences retrospectively. Both Gamified Poster and Gamified Quest received equal responses from four participants (25%) whereas Bingo! was the choice of three respondents (19%). Participants like P15 who “like painting” or P11 who valued “creativity and get extra points,” show the importance of diverse game types for different learners.

The second theme, Appreciation of format diversity, is captured in the response of P6, who declined to name a single preference, ‘I can not choose, I love all of them’. Representing just 6% of the sample, this response is nonetheless analytically valuable. It suggests that sustained exposure to a variety of game formats can produce a form of holistic engagement in which the value of gamification comes to feel greater than the sum of its individual parts.

Below shown combined version of Thematic analysis divide to 5 themes.

3.3.1 Affective Engagement was Near-universal and Multidimensional

The most consistent result in the entire semi-structured interview dataset was the strength and breadth of participant’s positive emotional responses to gamified

chemistry learning. All sixteen participants (100%) reported enjoying classes (Q1), and fifteen (94%) described explicitly positive emotional experiences during gamified activities, specifically motivation, joy, excitement, competitiveness, and a sense of preparedness (Q7). These figures represent the highest and second-highest prevalence rates recorded across any theme in the study. Critically, the emotional responses were not uniform in character, participants drew on a rich and varied vocabulary, pointing the likelihood that gamification engaged different learners through different emotional pathways.

3.3.2 Gamification was Considered Beneficial, Stimulating and Intellectually engaging

In Questions 2, 3, and 5, there is a recurring trend where a majority of respondents (between 75% to 87%) indicate that gamification helps improve their levels of motivation and increases their engagement in learning. Gamification was also perceived as being able to promote cognitive flexibility, creativity, and interdisciplinarity. This was demonstrated through P16, who realized that gamification connects chemistry to games in a way he did not expect, as well as P9, who found that artistic talents can be utilized in the classroom setting for sciences.

3.3.3 Constraints on Implementation were Recognized yet did not Lessen Support

A coherent minority existed in terms of analyzing the issues at stake, taking up 25%-44% of the responses given to Questions 5 and 6, pointing out tangible challenges in implementing gamification. Such limitations include the time and effort spent by the teacher on designing the lesson, the inability to adapt the gaming model for all types of lessons related to chemistry, the technical obstacles linked to lack of devices, poor quality of connection, the costs associated with particular platforms, and the challenges students might encounter while transitioning from gamified learning back to conventional lessons. It should be noted that such an attitude was always expressed next to the positive evaluation of gamification, which indicates that participants had no doubts regarding gamification per se but held a balanced dual perspective that

emphasized its pros over cons. This is best reflected in the responses to Question 6, where 44% pointed out the challenges while 81% identified its advantages.

3.3.4 Participants had Limited and Diverse Prior Knowledge

Question 4 revealed that almost two-thirds of respondents (69%) had some knowledge about gamification even before the start of the class, while one-third (31%) considered gamification a totally new concept. There are two reasons why this heterogeneity matters. First, it confirms that the broadly positive responses recorded across the semi-structured interview were not simply products of prior enthusiasm or self-reflection bias. It is shown in a substation minority arrived with no framework for understanding gamification and still reported high levels of engagement and enjoyment. Second, it suggests that the course successfully served a dual function with deepening existing familiarity with gamification as a pedagogical tool for those who already knew of it, while simultaneously introducing and legitimizing the concept for those who did not.

3.3.5 Diversity in Game Types was Indispensable for Inclusiveness

The distribution of game format preferences recorded to the exclusion of others. While Baamboozle was the most frequently preferred choice (31%), the Gamified Poster (25%), Gamified Quest (25%), and Bingo! (19%) all attracted meaningful levels of preferences, and one participant valued every format equally. This distribution carries a clear design implication, the hurseness of the gamified course was a product not of any individual game's qualities in isolation, but of the cumulative and varied exposure to multiple formats across the course as a whole. Different formats engaged different learner's profiles, competitive learner gravitated towards Baamboozle, creative learners toward the Gamified Poster, and socially oriented learners toward the Gamified Quest. Hence, diversity was not just an attribute of the course but a prerequisite for it.

Results of the research have been divided into two streams. The first one consists of the quantitative findings that were achieved through Mann-Whitney U-tests used for comparison of post-test scores for the experimental and control groups at three different

schools. The second stream is made up of qualitative findings gained using thematic analysis of the semi-structured interviews conducted with 16 participants.

Quantitative findings in all three scenarios (private school, lyceum, and public gymnasium), the experimental group outperformed their counterparts in terms of critical thinking and problem solving, which was statistically confirmed every time. When combined data of the three educational institutions were analyzed, it became clear that the differences were highly significant (critical thinking $U = 475$, $p < 0.001$; problem solving $U = 221$, $p < 0.001$), suggesting that the advantage was not limited to any specific setting but represented a general tendency resulting from gamification.

A private school revealed a statistically significant difference between groups in critical thinking ($U = 84.0$, $p < 0.001$) and problem solving ($U = 17.5$, $p < 0.001$). Not only did the experimental group show better results compared to the control group, but it was also more consistent since the experimental group showed lower values of the standard deviation and standard error of the mean. As for the lyceum, the most obvious effects were shown in problem-solving abilities ($U = 32.0$, $p = 0.019$); the same pattern can be traced as for other schools, namely, the greater stability in results with high central values. A public gymnasium provided statistically significant differences for both problem-solving ($U = 31.0$, $p < 0.001$) and critical thinking ($U = 38.5$, $p = 0.004$). These results carry particular significance since they belong to a certain educational institution rather than just an analysis of overall results.

Consistency appears consistently in all the three cases where, in each case, the experimental group demonstrates a better mean and median level of the post-test scores while, in most cases, achieving higher consistency in their scores. In particular, one can note lower standard deviations in the experimental groups. Moreover, consistency is even more pronounced when looking at an aggregated picture as the experimental group achieves half the level of standard deviation on the level of critical thinking skill (4.18 compared to 8.13). This means that, apart from better average results, gamification allowed for achieving more consistency in learning performance. However, there is only one partial exception to consistency in the experimental groups:

the variability in the level of the problem-solving skill was slightly higher in an aggregate one.

As far as the analysis of the semi-structured interviews is concerned, the main conclusions of this type of analysis include five key points, all contributing to explaining what the quantitative results represent and how exactly they were formed. However, the most interesting discovery of the entire process was the near-total positive affective involvement, which meant that all sixteen respondents felt that the classes were entertaining while fifteen reported highly positive emotions, such as excitement, motivation, competition, and fun, associated with gamified sessions. Considering the variety of emotional states generated by gamification, it may be argued that gamification worked through several different emotional channels.

In addition to the above affective perspective, an overwhelming majority of the respondents, between 75% to 87%, believed that gamification is motivational, intellectually challenging, and overall a positive aspect in developing critical thinking and problem-solving skills. The learners described gamification as one that fosters creativity and thinking beyond the boundaries of domains in ways that regular teaching methods had not managed to accomplish. Gamification also stretched the boundaries of learning as far as learners were concerned since several of them commented that they had been stretched to think in different ways in a science class before.

Practical limitations were acknowledged by minority. Concerns centred principally on the preparation demands on teachers, the difficulty of adapting game formats to every chemistry topic, and technical, also financial barriers to implementation. Crucially, these concerns were raised alongside positive evaluations rather than in opposition to them, reflecting a considered and balanced appraisal of gamification's real-world conditions rather than outright criticism. The heterogeneity of participant's prior familiarity with gamification shows that students positive outcomes to gamification does not come from pre-existing knowledge about it. And those who were not familiar with it reported high levels of engagement and enjoyment. Finally, the distribution of game format preferences across Baamboozle, Gamified

Poster, Gamified Quest and Bingo! underscored that no single format was responsible for the course's success, because variety in game design was itself a structural condition of inclusive engagement, with different formats drawing in different learner types.

Taken together, the quantitative and qualitative findings converge to support the rejection of the null hypothesis. Statistically significant differences in post-test critical thinking and problem-solving scores were observed between experimental and control groups across all three school contexts. And in aggregated sample, with p-values consistently below the 0.05 threshold, and in the majority of comparisons, below 0.001. Qualitative findings supports quantitative findings, showing positive affect of gamification to high school students. Accordingly, the alternative hypothesis, that gamification significantly fosters critical thinking and problem-solving skills in high school chemistry education is supported by the evidence.

DISCUSSIONS

4.1 Gamification and Critical thinking skill in Chemistry Education in High School

The quantitative findings of this study provide compelling evidence that gamification can be leveraged effectively to foster critical thinking in high school chemistry education. Across all three school settings a private school ($U = 84.0$, $p < 0.001$), a lyceum ($U = 32.0$, $p = 0.019$), and a public gymnasium ($U = 38.5$, $p = 0.004$) experimental groups achieved significantly higher post-test critical thinking scores than their control group counterparts, with the combined analysis confirming a highly significant and generalizable effect ($U = 475$, $p < 0.001$). These results are consistent with a body of evidence linking gamified instruction to the development of higher-order cognitive competencies.

Yıldırım et al. (2021) meta-analysis, which synthesized findings across multiple studies, reported a significant positive effect of gamification on academic achievement, lending broader statistical weight to the improvements absorbed here. More specifically relevant to critical thinking, Angelilli et al. (2023) demonstrated that carefully designed gamified activities can develop critical thinking skill by placing learners in scenarios that demand interpretation, reasoning, and evaluate judgement. Named processes that mirror the cognitive demands of the chemistry tasks used in the present study. In like manner, Chávez Suárez et al. (2024) demonstrated that gamification resulted in increased critical thinking skills among primary school children, while this study applies the same concept among secondary school students taking chemistry courses. Similar results were also observed by Ahmed et al. (2025), who stated that gamification promotes analytical thinking via competition and problem solving in online science education.

One such important outcome from the current study was the advantage provided by the consistency condition, whereby both the mean scores and standard deviations were lower in comparison to their counterparts, especially when it came to the overall sample group ($SD = 4.18$ compared to 8.13 for critical thinking skills). A meta-analysis

carried out by Zeng et al. (2024) indicated the role played by gamification in enhancing problem solving and critical thinking skills. The reduced variance observed here suggests that gamification may produce more equitable learning outcomes, narrowing the performance gap between stronger and weaker students. Ramazanov (2025) similarly reported that gamification in high school computer science led to more uniform skill development alongside engagement gains, suggesting that this equity effect may be subject-independent.

Importantly, pre-test equivalence was confirmed in the lyceum ($U = 63.0$, $p = 0.614$) and public gymnasium ($U = 86.0$, $p = 0.588$) samples, strengthening the internal validity of the post-test differences and allowing observed gains to be more confidently attributed to the intervention. The private school sample, where a pre-existing group difference was detected ($U = 90.0$, $p = 0.002$), necessitates a more cautious interpretation, as the post-test advantage of the experimental group may partly reflect baseline differences rather than the exclusive effect of gamification.

4.2 Gamification and Problem-solving skill in Chemistry Education in High School

The problem-solving results were, if anything, more striking than those for critical thinking. The lyceum produced the most powerful individual result across the entire dataset ($U = 7.50$, $p < .001$), with a mean difference of -10.0 points emerging from a position of complete baseline equivalence ($U = 72.0$, $p = 1.000$), rendering this finding particularly compelling. The private school yielded the largest absolute post-test mean difference in the study (-20.00), and the combined analysis confirmed a highly significant overall advantage for the gamified intervention ($U = 221$, $p < .001$), with a mean difference of -15.0 across all schools. These findings align with Sahito (2024) case study of STEM classrooms, which found that gamification strengthened problem-solving by placing learners in structured yet open-ended challenge environments that demanded strategy, iteration, and transfer. Abbassyakhrin et al. (2024) further established that gamification, in interaction with student's academic ability, produced gains in both metacognition and problem-solving, suggesting that the

game environment may activate self-regulatory processes that support deeper analytical engagement with chemistry content.

A literature review of game-based approaches in chemistry education covering the period 2019 to 2026 found that a range of higher-order thinking skills, were positively affected by gamification. Among them were reflective thinking creative thinking, computational thinking, design thinking, and problem-solving skills. Lutfi et al. (2023) demonstrated that game-based chemistry instruction improved both, motivation and retention of learning outcomes at the secondary level. It indicates that the mechanisms producing problem-solving skill gains operate over both, short and extended learning timescales. Temirbay (2025), working explicitly in the secondary school chemistry context, reported that gamified approaches to teaching organic compounds improved student's conceptual grasp and analytical application of content. It shows the cognitive demands that underpin successful problem-solving skill in chemistry.

The slight exception to the consistency pattern where the experimental group showed marginally greater variability in problem-solving at the private school and in the combined sample is worth examining. This may reflect the inherently divergent natures of problem-solving skills tasks during intervention, which elicit a wider range of individual responses or ideas to solve them when students are given the creative latitude that gamified environments typically provide. This interpretation is consistent with da Silva Junior et al. (2025) design rationale for Gamification 2.0, in which the elimination of traditional examinations in favor of gamified point accumulation produced a wide distribution of student performance. In fact, just because problem-solving activities in games involve different ways of solving problems.

4.3 Most Efficient Gamification elements for Development of Critical thinking and Problem-solving skills in Chemistry Education

According to the findings from the interviews conducted, there was no dominant preference for a particular game format among the participants. In detail, the games were divided into four different formats, namely: Baamboozle, Gamified Poster,

Gamified Quest, and Bingo!, representing 31%, 25%, 25%, and 19% support respectively. The implication of this is of great importance both theoretically and practically regarding the identification of the most powerful tools for building critical thinking.

Indeed, the success of Baamboozle among competitive learners in the current research is consistent with the already well-known fact about how leaderboards and competitive rankings improve academic motivation. That being said, leaderboards themselves do not automatically encourage thinking and solving problems; they need to be combined with activities that require analytical and synthesizing work. It seems that the Gamified Poster assignment, appreciated by one out of four respondents, successfully did that by asking students to create and visually organize chemistry-related materials. Such an assignment was noted by Nazneen (2024) as necessary for encouraging critical thinking through gamification.

Gamification elements can be understood as operating at three levels: dynamics (abstract elements such as emotions and narratives), mechanics (processes such as competition and feedback), and components (visible elements such as points, leaderboards, and badges). It means that effective gamification requires all three levels to interact (Ortiz-Rojas et al., 2025). The most complex formats based on the current study include the Gamified Poster and Gamified Quest format. The reason is that they contain narrative components and social interactions, which are lacking in the simpler quiz formats. It is plausible that learners have been cognitively engaged due to those additional components. This assumption correlates with the model suggested by Christopoulos (2023), where gamification in education relies on storytelling and creative challenges to encourage cognitive activity based on Bloom's taxonomy.

This time, the conclusion cannot be drawn casually, as it directly contradicts the hypothesis of the present study. As gamification does not induce an equal emotional response among students, the diversity of games incorporated into the intervention becomes more than just a desirable characteristic. In other words, if gamification cannot ensure that all learner profiles get emotionally engaged in activities, the

gamification process cannot resolve the issue of disengagement in the first place; on the contrary, it merely shifts it from one group to another. In addition to learning preferences, the cultural and sociological factors that play an essential role in gamification outcomes are gender identity and gaming experience, especially when talking about STEM subjects, which adds cultural connotations to these variables (Ortiz-Rojas et al., 2025). All these considerations lead to the ultimate conclusion that the effectiveness of gamification in a classroom environment does not lie in its presence alone. Rather, it depends on the thoughtfulness of gamification design and its ability to consider all intended recipient groups. Therefore, various learner profiles face game formats appropriate for them.

4.4 Perceptions of Students regarding Gamification in Chemistry Education at High School

The semi-structured interview used in this research generates very rich data. The 16 subjects all found the gamified classes to be enjoyable, while 15 expressed affective responses characterized by motivation, excitement, competition, and happiness. This is consistent with, and even surpasses, other literature on the topic.

In an exploration that utilized a mixture of quantitative and qualitative research approaches to examine the effects of gamification on students' academic success, significant improvements in performance were recorded along with very positive student perceptions about gamified classes. Student engagement and increased enjoyment became key themes in the qualitative aspect of the study (Duterte, 2024). Chans (2021) found similar results concerning motivation and engagement in chemistry courses within higher education, in which gamification led to sustained increases of motivation and engagement well after the novel phase of the experiment had ended. Of crucial analytical importance is the fact that in the present study, 69% of respondents were familiar with the concept of gamification, while 31% were not aware of gamification at all before enrolling in the course. These positive responses recorded during semi-structured interviews were not due to initial enthusiasm, but to the course design itself.

Based on the current research on the implementation of gamification in mathematics learning, it can be concluded that the greater engagement observed due to gamification involves both participation in activities and increased mental activity. Nonetheless, attitudes toward competition, autonomy, and failure tend to differ between various cultures or sub-groups, which makes it necessary to develop culturally tailored gamification solutions in order to provide equal opportunities for all participants (Ratinho et al., 2026). The design of the current study partially deals with this problem. The repetition of positive attitudes in three different schools – private, lyceum, and public gymnasium suggests that the effect of gamification is not dependent on socio-economic and institutional background.

One especially important finding relates to the dual perspective adopted by participants in terms of gamification. While 81% found the class interesting and engaging, 44% admitted to practical restrictions at the same time. The research literature shows that teachers experience certain problems in gamification due to lack of time for preparation of activities, little knowledge about gamification and difficulties related to organization of classroom space (Amjad et al., 2025). It can be concluded that participants of this study were aware enough of such restrictions without affecting their positive assessment of the course and that they demonstrate critical thinking skills in general as a result of gamification.

Recent research cautions that poorly implemented gamification, particularly when it places excessive emphasis on leaderboards, can demotivate certain learners and produce stress rather than engagement. It suggests that gamification is not a universal solution and that its success depends on context, content relevance, and careful design (Fodale, 2025). The present study's finding that no single format dominated and that different formats engaged different learner profiles directly addresses one risk. It was prevented by disturbing competitive, creative, social, and knowledge-testing elements across distinct game formats. The intervention avoided over-reliance on any single mechanic that the literature identifies as a design vulnerability.

Othman et al. (2024) described a gamified chemistry experience in which immersion in thematic game scenarios elevated both motivation and conceptual understanding, and Al-Ghawail (2022) documented similarly positive perceptions of Kahoot!-based chemistry gamification. The present study extends these findings by demonstrating that positive perceptions of this kind are robust across format types, school contexts, and levels of prior familiarity with gamification, and that they co-occur with statistically significant gains in the higher-order cognitive skills - critical thinking and problem-solving skills for the chemistry education.

CONCLUSION

This study set out to examine whether gamification could be effectively leveraged to foster critical thinking and problem-solving skills in high school chemistry education, and to understand how students perceive and experience gamified learning. The evidence gathered across three distinct school settings: a private school, a lyceum, and a public gymnasium, converges on a clear and affirmative answer to both examining.

Results derived quantitatively display an absolute lack of confusion. All experimental groups performed more effectively compared to their controls in the post-test assessments of both critical thinking and problem-solving abilities. In addition, the joint analysis reveals that this effect is not a consequence of the site-specific factors but rather a result of the positive influence of the gamified program itself. Taking into consideration that such effects occurred within three different high schools operating under unique organizational and socioeconomic conditions, one may conclude that the cognitive effects associated with gamification are universal enough to be achieved under any circumstances, irrespective of the surrounding environment.

Overall, the pre-test results confirm that the experimental and control groups were largely equivalent at baseline. At the lyceum, public gymnasium, and across the combined all-schools sample, pre-test mean differences in both critical thinking and problem-solving were negligibly small, indicating that the two groups began the study at comparable levels. The only exception was the private school, where the experimental group already held a statistically significant advantage in critical thinking before the intervention began. For problem-solving, baseline scores were comparable across groups at all three sites. These findings largely support the internal validity of the study, as the post-test differences observed can, in most cases, be more confidently attributed to the gamified intervention rather than pre-existing group differences.

These qualitative findings make it possible to answer those research questions where quantifiable data falls short. It turns out that the effect achieved was almost universally positive in terms of emotions experienced and involvement maintained

throughout the process. Perhaps even more important is the fact that the level of engagement went far beyond being simply enthusiastic. This becomes obvious when taking into account varying degrees of prior knowledge of gamification among respondents.

The participants recognized some constraints that exist. The pressure on the teacher to prepare for class, the difficulty of changing the format of the game to suit each new chemistry concept, and other obstacles associated with technical and monetary constraints should not be overlooked. For gamification to fulfill its evident promise, gamification needs more than just skilled teachers; it also needs the administrative backing of the school.

Taken all together, the results found from this experiment prove that the conscious incorporation of gamification in chemistry lessons at high school level is justified, according to the Manual outlined in Appendix 2 in p. 80. If carefully planned in such a way as to include diversity and instructional intent among other aspects, gamification can provide students with many advantages aside from simply enjoying learning about chemistry.

Hence, the null hypothesis should be rejected while supporting the alternative one. Gamification significantly fosters critical thinking and problem-solving skills in chemistry education in high school.

Future research should explore whether the gains in critical thinking and problem-solving skills observed here are retained over time, given the current findings are limited to the immediate post-test period. It would also be valuable to examine whether specific gamification formats are more effective for developing particular cognitive sub-skills, rather than treating higher-order skills as a undifferentiated outcome. Replicating this study across different cultural and linguistic contexts would further help to determine how broadly these findings can be applied.

SHORTCOMINGS AND LIMITATIONS

Several limitations of this study should be acknowledged. With respect to the third research question, which gamification elements are most effective for developing critical thinking and problem-solving skills in chemistry, the study was unable to provide a definitive answer. The gamified intervention was implemented as a holistic package comprising multiple game formats and elements. And no attempt was made to isolate or measure the contribution of each individual element separately. As a result, while the overall intervention demonstrably improved critical thinking and problem-solving skills outcomes, the data does not permit conclusions about which specific gamification element drove these gains.

Secondly, in the the private school the critical thinking skill pre-test already revealed a mean difference of -5.00 in favour of the experimental group, and this same difference persisted unchanged at post-test (-5.00), indicating that the intervention did not produce additional gains beyond the pre-existing advantage. This baseline imbalance was statistically significant ($U = 90.0$, $p = .002$), meaning that post-test critical thinking differences at the private school cannot be confidently attributed to the gamified intervention alone. In contrast, problem-solving pre-test means were equivalent across groups at the private school (mean difference = -5.00 , $U = 142.0$, $p = .105$), with the post-test difference widening substantially to -20.00 , providing stronger grounds for attributing this gain to the intervention. At the lyceum and public gymnasium, pre-test mean differences in critical thinking were close to zero, and problem-solving pre-test mean differences were likewise negligible across all sites, confirming baseline equivalence and lending greater internal validity to the post-test findings at those locations. When data were aggregated across all schools, the pre-test mean difference in critical thinking was effectively zero, confirming baseline equivalence between groups. At post-test, however, the mean difference widened to -5.00 , indicating that the observed gains are attributable to the intervention rather than pre-existing differences. Similarly, for problem-solving, the pre-test mean difference was negligible, while the post-test mean difference increased substantially to -15.0 .

This consistent pattern across both skills, whereby near-zero pre-test differences gave way to significant post-test divergence, provides strong cumulative evidence that gamification effectively enhanced both critical thinking and problem-solving skills across all school contexts. Another point to note is that students from private schools answered Question 3 correctly in both groups.

The suggestion is made to overcome certain restrictions in order for the teachers to use gamification in chemistry lessons. The idea is to use the Manual provided in Appendix 2 (p. 80) in order to design and integrate games with the help of instructions that will be based only on the websites that can be used for free, so that there would be no cost restrictions.

At the end, the choice of preferred games came strictly from the students' opinions gained through interview techniques rather than cognitive results separated based on game type. Therefore, any conclusion regarding which games might be better than the other can only be made hypothetically and cannot be proven based on current data. Future empirical investigations utilizing experimental methods will be necessary to resolve this matter further.

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APPENDICES

Appendix 1

1.1 Pre-test questions

1. Жер бетіндегі металдар өзінің сұлулығын көрсету үшін жарыс ұйымдастырды. Жарыс барысында әрбір метал өзін қасиеті мен сырт келбетіне байланысты түрлі теңеулер қолданды. Алтын сары жылтыры үшін өзін Күнге теңеді. Оның теңеуі көпшілікті қайран қалдырды. Осы сәтте оның қарсыласы өзін сұр жылтыры үшін Айға теңеп таныстырды. Бұл қандай метал?

Al Ag Mg Hg

2. Табиғаттағы фотосинтез процесі әуелден тіршіліктің негізі болды. Бұл процесске қатысатын қосылыстар жану процесінен алынған өнімдер болатын. Өсімдіктер бұл өнімдерді қолданып, ауаны ең қажетті газбен толықтырды. Бұл газбен қосылған сәтте құм түзіп, IV валенттілікті көрсететін элементті табыңыз.

Ne F S Si

3. Менің пішініме қарап, таныс емес адамдар жүзік деп атайды. Мен бұны атам Фарадей мен Гоффман тауып, маған қойған есімге құрметсіздік деп білемін. Мен кімін?

Толуол Бензол Аминқышықылы Майлар

4. Менің отбасым үлкен, біз бір бірімізге жеңіл түрлене аламыз. Әдеттегі дүйсенбіде менің бауырым жұмысқа барғысы келмейтінін айтты, оның орнына бару үшін маған тиімді ұсыныс жасады. Ұсынысты қабылдаған мен түрлену үшін Фридель-Крафтс ұсынған реакцияны қолдануды жөн санадым. Осы сәтте реакция үшін қажетті қосылыстың аяқталғанын байқадым. Түрленген келбет ұзақ тұру үшін маған қажетті затты табыңыз.

Галогеналқан, өршіткі қатысында

Циклоалқан, өршіткісіз Аминқышықылы, өршіткі қатысында

Карбон қышқылы, өршіткісіз

5. Күз, жақында күзгі бал болады. Бұл балда жеңіске жету үшін қолымнан келгеннің бәрін жасаймын деп нық бекіндім. Сұлудың сұлуы атану жолында түрлі “косметикалық” (ауыспалы мағына) заттарды қолдандым. Менің ажарымды айрықша аса түскен күміс-айна (реакциясы) болды. Бұл зат тек мен үшін ғана жаратылғандай сезілді. Мен кімін?

Кетон Аминқышқылы Альдегид Бензол

6. Біз үшін күн сәулесі азық жасау үшін таптырмас құрал болып табылады. Осы себепті де жаймашуақ жаз көңілімізге жағады. Азық жасау үшін бойдағы суды жерден жоғарыға көтеріп, ауадан көмірқышқыл газын күн сәулесі қатысында сіңірген сәтте жаңа бір тыныс ашылғандай күйге енеміз. Әсте бұл сезімді айтып жеткізу мүмкін емес. Сипатталған құбылыс пен түзілген азықтың дұрыс нұсқасын табыңыз.

Булану, фруктоза Хлорофилл, глюкоза Фотосинтез,
глюкоза Биосинтез, галактоза

7. The technology of laser beams is currently gaining great popularity. Using this technology, I immediately reached a volume 60 times larger than the original volume, and at the same time acquired the shape of a sphere. Who am I?

C S Fr Cl

8. Long ago, there was a time when there was no light at night on the streets. Whether it was a store, a hospital, a police station, or even the most mundane thing-knowing the time-it was difficult without gadgets. People were lost and searched for the safest and cheapest way to generate light that didn't rely on electricity. A solution was found, and humanity was saved. If you were to save humanity, what exactly would you use to power self-powering lighting devices?

Tritium Deuterium Hydrogen Helium

9. There were 118 of us friends, each of whom created a wonderful family after some time. Some lived in the air, others above ground, and I alone with my family remained somewhere in between. Over time, families similar in quality began to divide

into two groups: acidic and alkali. But I couldn't get into any of them, so I decided to look for similar ones. During my journey, I found my group. Find me and my group.

HF, basic Na_2O , acidic H_2O , neutral SO_2 , acidic

10. It's Nauryz 22, and there's a celebration in the courtyard. There was a huge prize in the tug-of-war (arkan tartys/перетягивание каната), and my twin brother and I wanted to win it, so we volunteered. My twin and I not only looked alike, but we were also equal in strength; the tug-of-war simply stood still, unmoving. As a result, we didn't win the prize. Now think about it, in the language of chemistry: who is more similar to us?

NaCl , ionic bond H_2 , non polar covalent bond Al_2O_3 , ionic bond HCl , polar covalent bond

11. Біз 4 ағайынды бауырлармыз. Бізді қолдану арқылы ғалымдар электронның күйін сипаттайды. Электронның күйін анықтау барысында бір ғалым ерекше заңдылықты байқады. Ол электрондар алдымен бос орбитальды бір-бірден толтарады деген шешімге келді. Бұл шешімді жасаған ғалымның атын табыңыз.

Д.И.Менделеев В.Паули Ф.Хунд А.Ампер

12. Ғалымдар жаңа заңдылықты күтіп, бір уақытта бірдей реакцияны жасады. Осы реакцияны жасау барысында алынған өнімнің массасы теориялық есептеудегі массаға сай келмейтіндігін байқады. Бұл мәселе ғалымдар арасында үлкен алаңдатушылық тудырды. Себебі өзге реакцияға қажетті жаңа заттың нақты мөлшерін алу үшін бір реакцияны бірнеше рет қайталап, көп уақыт жоғалтады. Осы мәселені шешу үшін сізден көмек сұрады. Бұл концепцияға қандай ат беретін едіңіз?

Ерітіндінің массалық үлесі Шығым Тығыздық Концентрация

13. Ертеректе органикалық химия есімді алып ағаш өмір сүріпті. Оның тамыры тереңде, бұтақтары көк аспанда еді. Осы ағаштың бұтақтары әр түрлі қасиетке ие болатын. Адамдар оны өз кәдесіне жарату үшін бар күшін салды. Әйтсе де өзіне қажет бұтақты алғашқы таңдаудан-ақ табу қиынға соқты. Осы

сәтте құпия ақылгөй мәселеге араласты. Ол осы бұтақтардың қасиеті мен ажырату жолын арнайы тақташаға жазды. Жыл сайын ағашта жаңа бұтақ өсіп, ақылгөйдің тақташасын өзге ғалымдар толтырып отырды. Соның бірі сізсіз. Сіздің бұтағыңыздың құрамында азот пен оттегі қана өзге бұтақтардан ерекшеліп тұратын. Бұл бұтақтың дұрыс атын табыңыз.

Нитроқосылыстар Аминқышқылдары Аминдер Фенолдар

14. Табиғатта қолданысқа жарайтын түрлі қосылыстар мен материалдар бар. Соның маңызды бір түрі мұнай болып табылады. Оның шикі түрі қолданысқа жарамайды, сол үшін оны арнайы температура мен қысымды қолданып, түрлі өнімдер алады. Осы процессті сіз басқарасыз. Дәл қазір дизельді отынға өте үлкен мөлшерде белгілі бір компаниядан тапсырыс түсті. Тапсырысты орындау үшін қандай фракцияны қолданасыз?

Газолин Лигроин Керосин Газойль

1.2 Post-test questions

1. Жер бетіндегі металдар өзінің сұлулығын көрсету үшін жарыс ұйымдастырды. Жарыс барысында әрбір метал өзін қасиеті мен сырт келбетіне байланысты түрлі теңеулер қолданды. Күміс сұр жылтыры үшін өзін Айға теңеді. Оның теңеуі көпшілікті қайран қалдырды. Осы сәтте оның қарсыласы өзін сары жылтыры үшін Күнге теңеп таныстырды. Бұл қандай метал?

Na Au Be He

2. Табиғаттағы фотосинтез процесі әуелден тіршіліктің негізі болды. Бұл процесске қатысатын қосылыстар жану процесінен алынған өнімдер болатын. Өсімдіктер бұл өнімдерді қолданып, ауаны ең қажетті газбен толықтырды. Бұл газбен қосылған сәтте улы қоңыр газ түзіп, осы қосылыста IV валенттілікті көрсететін элементті тап.

Ne F S N

3. Менің отбасым өте қызық, тап бір әртіс дерсің. Қышқыл секілді адамдарды сабасына түсіре алады, ал сілті мінезді жандар үшін көбіне өзі қышқылдай болып өзгереді. Осы екі қасиет отбасы мүшелерінде бір уақытта

болады, жай ғана әңгіме-дүкен құрып отырған адамның мінезіне қарай өзгереді. Осы әулет толықтай жиналған кездегі құрылтайды Нәруыз деп атайды. Мен қандай отбасыға жатамын?

Анилин Карбон қышқылы Эфирлер Аминқышқылдары

4. Әулеттің құрылтайы аяқталған соң әркім өз үйіне оралды; құрылтайға жалпы 20 отбасы қатысты. Аталған отбасыда белгілі бір реттік болатын, ең кіші отбасы мүшесі бірінші реттік, ал егде жастағы отбасы мүшесі төртінші реттікке жатады; бұл қағиданы қарт адамдардың өмірлік тәжірибесі мен даналығы арқылы түсіндіретін. Төменде көрсетілген отбасы мүшелерінің есімінен төртінші реттікке кім жататындығын анықтаңыз.

Аланин Серин Гемоглобин Глутамин

5. Кейде қажетті затты алу үшін бірнеше сағат немесе күндер күту керек болады, әсте де олай күтуге барлығында бос уақыт болмайды. Осы жағдайда көмекке өршіткілер келеді, олар реакцияға түспейді, бірақ жылдамдықты арттырады. Дәл осы қосылыстың қасиетін организмдегі белгілі бір нәруыздар атқарады. Ал аталған нәруыздар ДНҚ синтезіне қатысатын болса, оның құрамында Урацил бар “туысының” қандай химиялық байланысты көрсететіндігін анықта.

Сутектік Иондық Күкірттік Металдық

6. Адам организмі дұрыс жұмыс жасау үшін түрлі минералдар мен элементтерді қажет етеді. Осыны химия сабағынан үйренген Амина (кез-келген ұқсастық жәй ғана сәйкестік болып табылады) күнделікті өмірде өзін бақылай бастады. Ол орнынан тез тұрған кезде көзі қарауытып, бас айналуын байқады. Уақыт өте келе көп есінеп, шаршағыш болып кетті. Осы белгілерді кітаптағы ақпаратпен салыстыра отырып, қандай элемент жеткіліксіз болғандығын анықтау үшін анализ тапсырды. Анализ нәтижесіне қарап анемия диагнозы қойылған болса, жеткіліксіз болған элементті табыңыз.

Калий Магний Кальций Темір

7. The work of the human body has long been of interest to all scientists. It has been found that the body's ability to function only non-stop depends on the organelle from which the body generates energy. What is the sign of Gibb's energy during hydrolysis of the resulting energy?

Positive Negative It is not shown

8. The little boy wondered why it was necessary to eat regularly, because he always wanted to play games, and asked if he could eat one meal and play for at least three days. To find the answer to the question, he asked all the adults, and according to the answer received, he realized that it was necessary to go to the great chemist. You're the same great chemist. To solve and to explain the answer of this problem, choose the most correct and chemical option.

In chemistry, this thing is not fully studied. However, the need for constant nutrition is known to everyone.

Nutrition is a natural necessity. Just like sleeping. I am sure that this question has nothing to do with chemistry.

Some organisms, such as plants, make glucose by using carbon dioxide and water as their food. It is necessary to take food from the outside, since a person does not have the ability to produce its own food.

Substances that enter the body are quickly broken down under the influence of a catalyst. Then they go to the right place and are used. Each time a need arises, a person is attracted to a specific food. For this, a person needs to eat regularly.

9. Scientists have tried to make various reactions and race them to speed. A special gift was prepared for the scientist, whose reaction ended quickly. To do this, each scientist conducted his secret reaction regarding the acceleration of the reaction. It was time for the race, and when the reaction rate dropped, the first scientist added the reagent to it, the second scientist added the catalyst, and the third changed the pressure. However, their results did not last long, as no one fully studied how the speed changes. At this moment, a scientist named Van'T Hoff appeared in the middle to share

his knowledge with others without envy. If you were in his place, what formula would you create to solve this problem?

a) $r(T1)r(T2)=(T2-T1)/2$ b) $r(T2)r(T1)=(T2-T1)/10$ c) $r(T2)r(T1)=(T2-T1)/5$ d) $r(T1)r(T2)=(T2-T1)/10$

10. There was a new reaction in nature. At this time, the reagents reacted to form a product, which scientists called a direct reaction. However, the next scientist, observing the reaction, found that the mass of the original substance did not change from here. According to a long study, the products formed during the reaction reacted together and decomposed into a reagent, which gave the reaction the name of the reverse reaction. However, the fact that these two reactions occurred at the same time seemed to be unchanged to the outside, so many scientists abandoned the field of chemistry until the reaction did not take place. You are taking the first step in chemistry, and you did not want others to repeat this situation. The first step we took for that was to give a name to this reaction. Which of the lower versions will be the new name?

Synthesis Chemical equilibrium Burning Hydrolysis

11. Біздің отбасымызда көп ағайынды едік. Есіміміз бір-біріне ұқсас болу үшін ата-анамыз соңына “-ан” жұрнағын жалғаған болатын. Қанша жерден ата-анасы бауырларды ұқсас болғанын қаламастан, олардың табиғаты мен мінезі әр түрлі еді. Соның нәтижесінде ешбір бауырдың мамандығы бір-біріне ұқсамады. Мамандығына сәйкес олардың есімдерінің алдына тағы да бірнеше сипаттамалар қосылды. Төмендегі нұсқадан галогеналқан мамандығына сәйкес есім мен сәйкес галогеннің химиялық формуласын табыңыз.

C₄H₈Cl₂, Cl C₅H₁₂Br, Br C₄H₇I, I C₂H₂F₃, F

12. Ерте заманда химиялық реакцияны жүргізген ғалымдар сиқыршыға тең еді. Себебі реакция нәтижесіндегі өзгерістерді барлығы бірдей түсіне алмайтын. Соның бірінде алкеннің галогенсутекпен қосылу реакциясында бірдей зат қолданылғанына қарамастан, әр реакцияда соңында әр түрлі өнім алынатын. Бұл жағдай өнімді қолданатын реакцияны жүргізуге кедергі жасайтын. Бұл мәселені шешу жолында талай ғалымның тері төгіліп, сиясы кепті. Уақыт өте

келе алынған өнімнің түзілуінің пайыздық көрсеткіші әр түрлі екендігі анықталды. Әйтсе де, бұл реакцияның түсіндірмесін жазы оңай болмады. Сіз осы жолда қызмет жасаған В.В.Марковниковтің шәкірті болдыңыз. Оның ізбасары ретінде бұл мәселенің шешімін өзге ғалымдарға түсіндіріңіз.

Алкенде тек дара байланыс, сол үшін реакция рандом түрде жүреді, сәйкесінше алынатын өнімді болжау мүмкін емес.

Алкенде қос байланыс бар, галогенсутектегі сутек қос байланыстағы көпсутекті көміртек атомына қосылады және оның өнімі көп мөлшерде түзіледі.

Алкенде қос байланыс бар, галогенсутектегі галоген қос байланыстағы көпсутекті көміртек атомына қосылады және оның өнімі көп мөлшерде түзіледі.

Алкенде қос байланыс бар, галогенсутектегі сутек қос байланыстағы азсутекті көміртек атомына қосылады және оның өнімі көп мөлшерде түзіледі.

13. Жаңадан анықталған химиялық қосылыстың құрылымы алкенге ұқсас, алайда жалпы формуласы алкинмен бірдей. Бұл затты С.В.Лебедев түрлі оксидтерді катализатор ретінде қолдана отыра өнім ретінде алды. Осы жаңа затты қолдану арқылы полимер көксағыз пайда болды, оны өңдеп бізге таныс резеңкені қолданысқа енгізді. Резеңкенің қолданыс аясының үлкендеуіне байланысты қолданылған бастапқы шикізатқа үлкен сұраныс түсті. Бұл шикізатты өндірумен сіз айналысасыз. Сұранысты толықтай қанағаттандыру үшін реакцияны өзге ғалымдармен бөлісу туралы шешім қабылданды. Реакцияны түсіндіруді жеңілдету үшін бұл жаңа өнімге химиялық құрамына сай есім беру керек. Төмендегі нұсқадан дұрыс есім мен қолданылған катализаторларды таңдаңыз.

Алкадиен, Al_2O_3 , Cr_2O_3 Алкадиен, Al_2O_3 , FeO Алкадиен, Cr_2O_3 , FeO Алкадиен, Al_2O_3 , ZnO

14. Алкиннің химиялық ерекшелігі үшін қосылу реакциясы үнемі сатылап жүретін. Бірақ бұл заңдылыққа бағынбайтын су алкиннің бір түрі пропинмен әрекеттескенде алғашқы сатыда-ақ толықтай реакцияға түседі. Оның осы бірбеткейлігіне көңіл-күйі қатты әсер ететін. Бірде көл, бірде шөл болып жүрген сумен пропиннің реакциясы нәтижесінде екі түрлі зат түзілетін. Бұл

реакцияны жүзеге асыру барысында өте улы сынап өршіткі ретінде қолданылатын. Оның уы адам ағзасына келтіретін зияны орасан зор. Осы уды жою үшін А.Шәріпқанов ерекше әдіс ұсынды. Бұл әдістің мәселені қалай шешетіндігін төмендегі нұсқаны таңдап түсіндіріңіз.

Бұл реакцияны сынаппен бірге темірдің (II) тұздарының қатысында жүргізу керек, сонда сынаптың катионы түзіліп, у жойылады

Бұл реакцияны сынаппен бірге темірдің (III) тұздарының қатысында жүргізу керек, сонда сынаптың катионы түзіліп, у жойылады

Бұл реакцияны сынаппен бірге алюминийдің (III) тұздарының қатысында жүргізу керек, сонда сынаптың катионы түзіліп, у жойылады

Бұл реакцияны сынаппен бірге хромның (II) тұздарының қатысында жүргізу керек, сонда сынаптың катионы түзіліп, у жойылады

QR code to the Manual



Table A3.1. Ranks of pre-test questions from validity

	Mean Rank
Q1	10,00
Q2	3,88
Q3	3,88
Q4	10,00
Q5	11,50
Q6	4,25
Q7	5,13
Q8	11,50
Q9	4,13
Q10	4,25
Q11	8,38
Q12	5,13
Q13	11,50
Q14	11,50

Table A3.2. Ranks of post-test questions from validity

	Mean Rank
Q1	10,13
Q2	2,88
Q3	10,13
Q4	10,13
Q5	3,13
Q6	10,13
Q7	10,13
Q8	5,25
Q9	2,88
Q10	10,13
Q11	7,75
Q12	8,63
Q13	3,63
Q14	10,13

Table A3.3. Ranks of semi-structured interview questions from validity

	Mean Rank
Q1	5,13
Q2	1,13
Q3	5,13
Q4	4,13
Q5	5,13
Q6	5,13
Q7	5,13
Q8	5,13

4.1 Private school

Table A4.1.1. Assumptions. Normality

	W	p
Post-test.CT	0.709	<.001

Note. A low p-value suggests a violation of the assumption of normality

Table A4.1.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test.CT	8.23	1	38	0.007

Note. A low p-value suggests a violation of the assumption of equal variances

4.2 Lyceum

Table A4.2.1. Assumptions. Normality Test

	W	p
Post-test.CT	0.910	0.035

Note. A low p-value suggests a violation of the assumption of normality

Table A4.2.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test.CT	8.81	1	22	0.007

Note. A low p-value suggests a violation of the assumption of equal variances

4.3 Public gymnasium

Table A4.3.1. Assumptions. Normality Test

	W	p
Post-test.CT	0.844	<.001

Note. A low p-value suggests a violation of the assumption of normality

Table A4.3.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test.CT	6.85	1	26	0.015

Note. A low p-value suggests a violation of the assumption of equal variances

4.4 All school

Table A4.3.1. Assumptions. Normality Test

	W	p
Post-test. CT	0.805	<.001

Note. A low p-value suggests a violation of the assumption of normality

Table A4.3.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test. CT	9.07	1	90	0.003

Note. A low p-value suggests a violation of the assumption of equal variances

5.1 Private school

Table A5.1.1. Assumptions. Normality Test

	W	p
Post-test. PS	0.884	<.001

Note. A low p-value suggests a violation of the assumption of normality

Table A5.1.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test. PS	4.77	1	38	0.035

Note. A low p-value suggests a violation of the assumption of equal variances

5.2 Lyceum

Table A5.2.1. Assumptions. Normality Test

	W	p
Post-test. PS	0.849	0.002

Note. A low p-value suggests a violation of the assumption of normality

Table A5.2.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test. PS	5.53	1	22	0.028

Note. A low p-value suggests a violation of the assumption of equal variances

5.3 Public gymnasium

Table A5.3.1. Assumptions. Normality Test

	W	p
Post-test. PS	0.872	0.003

Note. A low p-value suggests a violation of the assumption of normality

Table A5.3.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test. PS	6.31	1	26	0.019

	F	df	df2	p
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Note. A low p-value suggests a violation of the assumption of equal variances

5.4 All school

Table A5.4.1. Assumptions. Normality Test

	W	p
Post-test. CT	0.805	<.001

Note. A low p-value suggests a violation of the assumption of normality

Table A5.4.2. Assumptions. Homogeneity of Variances Test

	F	df	df2	p
Post-test. CT	9.07	1	90	0.003

Note. A low p-value suggests a violation of the assumption of equal variances

6.1 Answers of the semi-structured interview

Answers of Semi-structured Interview

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
P1	Yes	Yes, it was enjoyable	Course was engaging	Yeah, I knew basics	They make learning more fun	Motivation and engagement, but can be distracting	I feel motivated more interested during lessons	Baamboozle
P2	Yes	Yes	Lessons were interesting	I knew it	They make me more motivated	Its hard to implement to some themes	I felt interested	Gamified poster
P3	Yes	Yes	I like these course	No	I want it all the time	Active participation, no disadvantages	It make me feel engagement	Gamified poster
P4	Yes	Yes, I liked games	Its interesting	I heard about it	I want to make my own games too	Connect between teacher and student, no advantages	I was motivated	Gamified quest
P5	Yes	Yes, they motivated me	Course was enjoyable	Yes, I did	It helped me to broaden my horizons	I think not every student will like specific games	I felt competitiveness	Baamboozle, Gamified quest
P6	Yes	Yes, I understand topics	I love it	Yeap	It changed general chemistry lesson	There is a lots of materials for use, it will be hard for teacher to prepare all of them	I felt adaptation for new things	I can not choose, I love all of them
P7	Yes	Of course	It was easy	I do	I did not know that its applicable with chemistry	Students participation, but for a non competitive students it will be a little bit	It made me interested in chemistry	I liked Baamboozle most, because my group won it

						harder to play		
P8	Yes	Yeap, I liked games	I enjoyed lessons	Yes	I want lessons like that one more time	It's interesting, but it takes time, there is a chance groups won't make it in a time	I felt myself prepared	Gamified quest, I liked to find specific items
P9	Yes	Yes, activities were new	I like everything	Yes	It helped me use my art talent in chemistry	I think there is no disadvantages	I felt joy	Gamified poster
P10	Yes	Yes, I do	It was interesting	No	I never ever expected chemistry lesson enjoyable like that	Its fun, but there might be sudden problem with devices for game	I was excited every lesson	Gamified poster, I missed to do posters
P11	Yes	Yes, I am interested	Course was fast	Not sure	I played games during lessons only at primary school	I heard that some platforms for games are on fee-paying based to use	I was prepared for every possible games during implementation	Gamified quest, I was responsible for creativity and we get extra points
P12	Yes	Yes, I wanted something like that	It was engaging	Yes, I did	Games were so good, I want to play them all the time not only in the chemistry lesson	Confidence and differentiation in lessons. Also it takes time to prepare	I felt good	BINGO! It was the easiest one for me
P13	Yes	Yes, I love new things	I was interested	Yeah, I knew about it	They helped to contact with my classmates, and made it interesting	When student adapts to games, it will be hard for him to study traditionally	I knew that my academic performance was better by time	Baamboozle, I liked its random boxes
P14	Yes	Yes, I was looking for something like that	I liked that	Yes	I felt motivated and competitiveness helped me to be ready for	I see no disadvantages	I feel excitement from new games	Gamified quest, I find code of the door

					new lesson to get points			
P1 5	Yes	Yes, I got themes	It was specific	I knew	I Competitiveness was raised during lessons, I liked it	Its hard to find ideas for game I think	I feel relaxation, because during games responsibilities are equal in groups	Gamified poster, I like painting, and finally I was able to use it in chemistry
P1 6	Yes	Yes, I love group activities	I want to took course one more time	I was familiar with it	I think it made my mind flexible, I never ever expected that chemistry and games are connected	Games helps to make topics easy and learn it gradually, no disadvantages	I felt envy for groups that got first place during games	BINGO! First game felt different

6.2 Semi-structured interview questions

1. Did you like the chemistry education classes?
2. Were class activities nice? Why and why not?
3. What do you think about this course?
4. Are you knowledgeable about gamification applications?
5. What do you think of gamification applications?
6. In your opinion, what are the strengths and weaknesses of gamification applications?
7. How do you feel about gamified activities during Chemistry lessons?
8. Which game do you like most?