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Mastering Organic Chemistry Via OrganiX Battleship Games: A Statistical Study

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Abstract: *Organic chemistry is a branch of chemistry that focuses on the study of the structure, properties, reactions, and synthesis of carbon-containing compounds. Some students find organic chemistry is challenging due to its complexity and the need to understand intricate molecular structures and memorizing the reactions. This innovation developed a learning tool that integrate organic chemistry content into 2D mobile game namely OrganiX Battleship. This game aimed to keep the students engaged and motivate them, to study anywhere and anytime by using mobile platform. The game was incorporated with exercises with different difficulty level tailored with the learning module. This OrganiX Battleship is used in Chemistry 2 course for Sciences students in Centre for Foundation Studies, IIUM. A combination of descriptive statistics, specifically mean values, and inferential statistics using Partial Least Squares Structural Equation Modelling (PLS-SEM) was adopted to gain a comprehensive understanding of the impact and dynamics of the gamification approach. Results revealed that OrganiX Battleship increase their understanding, motivation, and engagement in learning organic chemistry. Gamification alleviates the monotony of studying chemistry, making it more engaging for students and enhancing their ability to memorize organic compounds and reactions. This OrganiX Battleship mobile game has potential for commercialization that can create a compelling and engaging mobile gaming experience.*

Keywords: Educational Game, Organic Chemistry, PLS-SEM, 2D Mobile Game

1. Introduction

General chemistry serves as a foundation for further studies in chemistry and related fields such as organic chemistry. However, the topics studied in these two courses are very different. While general chemistry largely relies on mathematical analysis, organic chemistry focuses more on the relationship between structure and reactivity (Halford, 2016) and on more difficult intellectual tasks that are more prone to alternative conceptions (McClary & Bretz, 2012; Rushton et al., 2008). Reinforcing understanding of organic chemistry's relationships and tasks requires practice. These are the parts where students always find difficulty to understand and learn organic chemistry. Organic chemistry has always been considered a difficult topic (O'Dwyer & Childs, 2017).

For years organic chemistry has been taught traditionally whereas majority aware that organic chemistry often requires students to develop strong spatial and molecular visualization skills. Thus, some students face the difficulty to grasp the concepts of this organic chemistry and find this aspect challenging. It also may lead to students' misconceptions. Following this consideration, several methods of teaching and learning such as blended learning or flipped classroom can be adopted to help students in understanding the organic chemistry. Blended learning is one of the methods to combine traditional face-to-face classroom teaching with online learning activities. It integrates different modes of instruction, utilizing both physical and digital environments to enhance the learning experience. Brown, 2012 supplemented lectures with videos and animations to help students learn and understand mechanism of organic chemistry. Students reported that the use of online learning resources improved their understanding and ability to confidently apply the mechanism knowledge. On the other hand, flipped classroom is also can be used in teaching organic chemistry where students are given first with instructional content outside of class, typically through online videos, readings, or other multimedia resources. Class time is then used for active learning activities, such as discussions, problem-solving exercises or collaborative projects, where students can apply and deepen their understanding of the pre-studied material. Leo and Puzio (Leo & Puzio, 2016) found out that the findings of their work showed that students preferred watching video lectures outside the classroom and appreciated being actively engaged in the classroom. Schultz et al., 2014 also found that the flipped classroom helped high school advanced placement chemistry students to understand the chemical concepts for the whole academic year.

Other than the use of online learning resources, game-based learning also offers comprehensive learning experience. Several established game-based learning platforms, among others are Quizizz, Kahoot!, and Socrative, are known to be highly effective in enhancing the educational experience, making learning more interactive, enjoyable, and impactful (Temel & Cesur, 2024). These game-based learning systems incorporate gamification elements like points, rewards, leaderboards, and varying levels of difficulty, making them an effective formative assessment tool in the learning process or as a break from traditional classroom activities. In gamification, the game elements are handled in two ways: self-elements and social elements (Kamalodeen et al., 2021). Self-elements may include scores, achievement badges, levels, or time constraints. These elements enable students to focus on competing with themselves and recognizing their achievements. As for social elements, these are concerned with interactive competition or cooperation, such as leaderboards. These elements bring students into a community with other students, and their progress/successes are announced (Huang & Soman, 2013).

The interests of Generation Alpha, who were born after 2010 and growing up with technology) overlap with their usage and involvement in mobile games, typically played on smartphones or tablets. Research on Gen Alpha's gaming habits reveals diverse preferences and usage patterns. A longitudinal study by Arabiat et al., 2023, documented a shift towards mobile devices as the primary gaming platform among younger children. Furthermore, Denden et al., 2021 identified gender differences in game genre preferences, suggesting implications for game developers and educators. Mobile games also play a significant role in shaping social interactions among Gen Alpha. According to Zomer et al., 2021, multiplayer mobile games help develop collaboration and teamwork skills in young players. Multiple studies emphasize the educational advantages of mobile games for Generation Alpha. For example, Firipis et al., 2018 discovered that educational mobile games can improve cognitive abilities like problem-solving and critical thinking. Likewise, Adeshola & Agoyi, 2023 showed that interactive learning applications engage young learners and enhance their retention of academic material.

In this research, a study was designed to achieve a twofold purpose; that is to evaluate the effectiveness of OrganiX Battleship mobile game in enhancing motivation, understanding and memorization of organic chemistry subject and on the other hand to study the behavioral impact of students towards the gamification in chemistry subject. This study was conducted by Chemistry Department that involved students from various programs taking organic chemistry during academic year 2023/2024 at the Centre for Foundation Studies, International Islamic University Malaysia (CFSIIUM). To thoroughly understand the effects and dynamics of the gamification approach, both descriptive statistics, such as mean values, and inferential statistics, specifically Partial Least Squares Structural Equation Modelling (PLS-SEM), were utilized. It is expected that OrganiX Battleship mobile game will give significant impact towards students' interest and influenced the behavioural intention of student to increase their understanding on the topic of organic chemistry. Taking into consideration that the current students are more inclined to gadgets, this study is also expected to contribute to a new interesting measure of teaching organic chemistry in CFSIIUM.

2. Methodology

To obtain quantitative data for this study, a survey research approach was used. The questionnaire featured a 5-point linear scale for numerical ratings. Respondents assessed their perceptions across six constructs, comprising 19 indicators. The data were collected from students at the Centre for Foundation Studies of International Islamic University Malaysia (CFSIIUM) across various programs who had taken organic chemistry course during academic year 2023/2024, semester two (2). The collected data were analysed using mean value and PLS-SEM to achieve the mentioned objectives.

Population and sampling

The population that involved in this present research work consist of 75 students taking Chemistry 2 in Semester 2, 2023/2024. In this study, a voluntary sampling technique was employed and a total of 67 students were the respondents. This approach allows us to gather data from individuals who are genuinely interested in the subject matter, potentially leading to more engaged and thoughtful responses.

Data collection method

To collect data for this study, a questionnaire survey was distributed through an online form to obtain quantifiable information about students' experiences with the OrganiX Battleship game. The questionnaire was designed to assess various aspects based on theory of planned behaviour that include attitude, subjective norm, perceived behavioral control, knowledge and learning satisfaction that could contribute to the intention of students to use gamification as part of their learning process.

Data analysis technique

The collected data were analyzed based on descriptive analysis to evaluate the effectiveness of the gamification approach. Mean values summarized the central tendency of the responses, while Partial Least Squares Structural Equation Modeling (PLS-SEM) examined the relationships between variables. This combination of techniques provided a robust analysis, enabling a comprehensive evaluation of the OrganiX Battleship game's impact on the intention of students to use gamification during the teaching and learning.

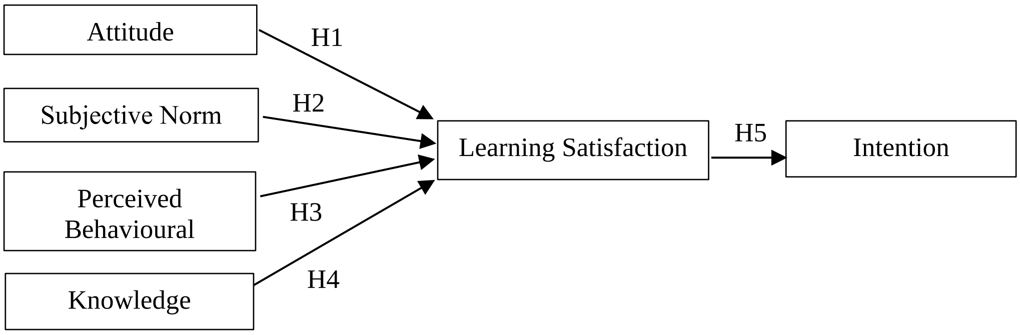

Figure 1: A proposed research framework

The theory of planned behavior (TPB) a cognitive theory by Azjen (1985) proposed that an individual's decision to engage in a specific behavior (Ajzen, 1985). In the present work, an extension of the TPB was adopted and applied to study on the following predictors toward the intention of students to use gamification approach in teaching and learning Organic Chemistry subject in CFS IIUM. This research tested the following hypotheses at 0.05 significant level;

Attitude

Essentially, attitude is defined by how a person behaves, which in turn affects their actions. In the context of education, a positive attitude supports a student's knowledge and enhances their learning activities. Without good behavior, even a high level of knowledge becomes ineffective. Attitude is a reflection of one's thoughts and experiences, manifested through behavior (Jefferies, 2023). Our attitudes can either facilitate or hinder our actions. This study focuses on students' attitudes in relation to their learning process within the program. Based on the above statements, the following hypothesis can be expressed:

H1: *Attitude for gamification has a positive influence towards student's learning satisfaction.*

Subjective Norms

The subjective norm refers to an individual's perception of the beliefs and expectations of others, which influences their decision to engage in or avoid a particular behavior (Engbers, 2023).A student's intention to pursue this program may be shaped by the opinions and judgments of significant others, such as parents, spouses, friends, and teachers. Thus, the hypothesis can be stated as follows:

H2: *Subjective norm has a positively towards student's learning satisfaction.*

Perceived Behavioral Control

Perceived behavioral control demonstrates an individual's perception of their ability to achieve a specific behavior (Ajzen, 1985). This concept relates to how people perceive their capacity to show certain behaviors. According to Ajzen, perceived behavioral control is based on control beliefs, which are the individual's beliefs about the presence or absence of factors that facilitate or hinder the performance of the behavior. Therefore, the hypothesis is presented as follows:

H3: *Perceived behavioural control has a positive influence towards student's learning satisfaction.*

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Knowledge

Knowledge is a result of processing an object or a phenomenon using human sensing, namely, the senses of hearing, sight, smell, feeling and touch, then completed the process by referring to previous information related to. According to (Vereijken & van der Rijst, 2023), knowledge is a theoretical and practical understanding of certain subject matter which contains a number of particulars in the form of facts, methods, or ways of doing things. A student's knowledge is indispensable in achieving the learning outcomes upon completing the programme of the foundation. Accordingly, the hypothesis can be presented as:

H4: *Knowledge integrated in gamification positively influences towards student's learning satisfaction.*

Learning Satisfaction

Learning satisfaction through gamification examined how it impacts users' sustainability knowledge and intentions (Abou Kamar et al., 2024). They found that the perceived usefulness, ease of use, and enjoyment of the gamified experience significantly enhance users' knowledge, which in turn positively influences their intentions. This approach can be applied to educational settings to measure and improve learning satisfaction through gamified learning experiences. Hence, the hypothesis can be drawn as follows:

H5: *Student's learning satisfaction has a positive influences towards the intention student to use gamification in learning.*

3. Results and Discussions

In this section, the study findings on assessing how the OrganiX Battleship mobile game improves students' comprehension of organic chemistry concepts compared to traditional learning methods are presented. This section begins with basic statistical analysis of descriptive analysis using SPSS, to address objective one. For objective two, advanced statistical analysis using Partial Least Squares Structural Equation Modeling (PLS-SEM) is conducted.

3.1 Descriptive Analysis

For this study, univariate descriptive analysis was employed, as shown in the following tables and figures.

Gender: The gender of the respondents as provided in Table 1

Table 1: Gender frequency distribution of respondents

Gender	Frequency	Percentage (%)
Female	46	69
Male	21	31
Total	**67**	**100**

Out of all respondents, forty-six were female (69%) and twenty-one were male (31%). This data indicated that majority of the respondents are female.

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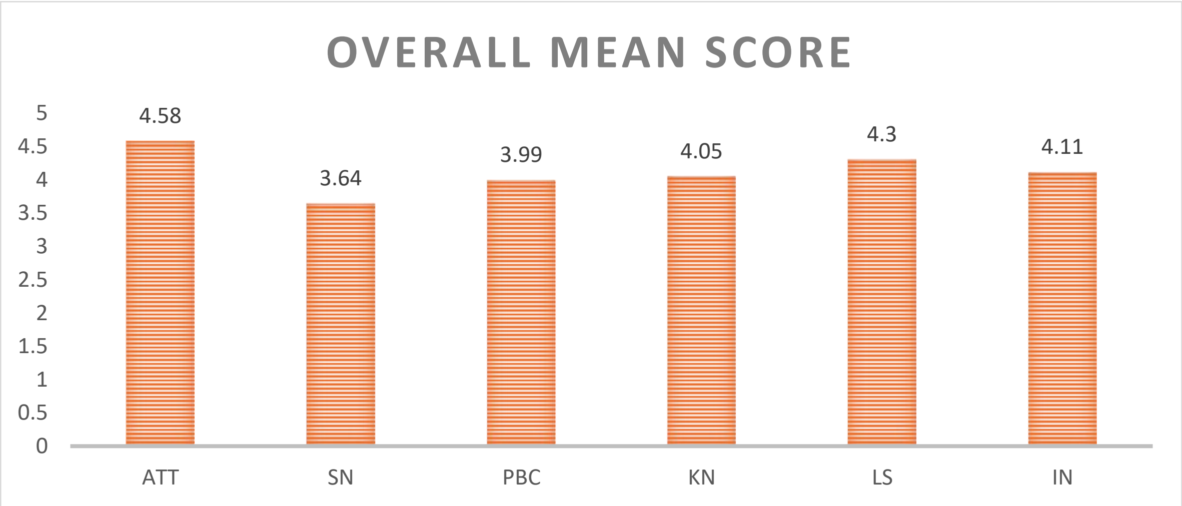
Program: The academic program of the respondents as provided in Table 2

Table 3: Respondents' graduation year

Program	Frequency	Percentage (%)
Medical	16	24
Nursing	11	17
Pharmacy	21	31
Physical Science	19	28
Total	**67**	**100**

Based on Table 3, most of the respondents are students enrolled in the pharmacy program, accounting for twenty-one respondents (31%). This is followed by the physical science program with nineteen respondents (28%), the medical program with sixteen respondents (24%), and the nursing program with eleven respondents (17%).

Respondents' Perception on the Effectiveness of the OrganiX Battleship Mobile Game Implementation: The respondents' perceptions of the OrganiX Battleship mobile game implementation regarding attitude, norm, behavior, knowledge, learning satisfaction, and intention are presented in Figure 2. The mean score was utilized to evaluate respondents' perceptions of mobile game implementation.



Note: ATT is Attitude; SN is Subjective Norm; PBC is Perceived Behavioural Control; KN is Knowledge; LS is Learning Satisfaction; IN is Intention.

Figure 2: Overall Mean Score of Respondents 'Perception Towards the Effectiveness of Organix Battleship Game in Learning Organic Chemistry.

The majority of respondents have a positive perception of implementing the gamification approach in learning organic chemistry, specifically through the OrganiX Battleship mobile game. The mean values for various TPB constructs are as follows: Attitude (ATT) 4.58, Subjective Norm (SN) 3.64, Perceived Behavioral Control (PBC) 3.99, Knowledge (KN) 4.05, Learning Satisfaction (LS) 4.3, and Intention (IN) 4.11. These values are notably high, typically above the midpoint of the 1 to 5 numerical scale, indicating a strong positive response. This finding aligns with previous studies on the impact of gamification in the learning process using TPB (Motazedian et al., 2024)(Aries et al., 2020), which also explored how TPB constructs influence students' adoption of gamification, engagement, and overall learning outcomes in different field. The consistency with earlier research supports the effectiveness of gamification in enhancing learning experiences.

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3.2 Advance Statistical Analysis

To address objective two of this study, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed. The advanced statistical analysis proceeded with the assessment of the measurement model and the structural model, using PLS-SEM with SmartPLS software.

Full model of OrganiX Battleship mobile game in relation to learning organic chemistry. The full model for this study was developed using SmartPLS by running the PLS algorithm with the path weighting scheme, as illustrated in Figure 3, which displays both the measurement model and the structural model. The measurement model (outer model) depicts the relationships between manifest variables (i.e., items/indicators), represented by rectangular shapes and their latent variables (i.e., constructs), represented by oval shapes. The structural model (inner model) illustrates the relationships among the latent variables.

The full model of this study consists of six latent variables: attitude, subjective norm, perceived behavioral control, knowledge, learning satisfaction, and intention. All six latent variables; the first order constructs were reflective measured by a total of nineteen manifest variables.

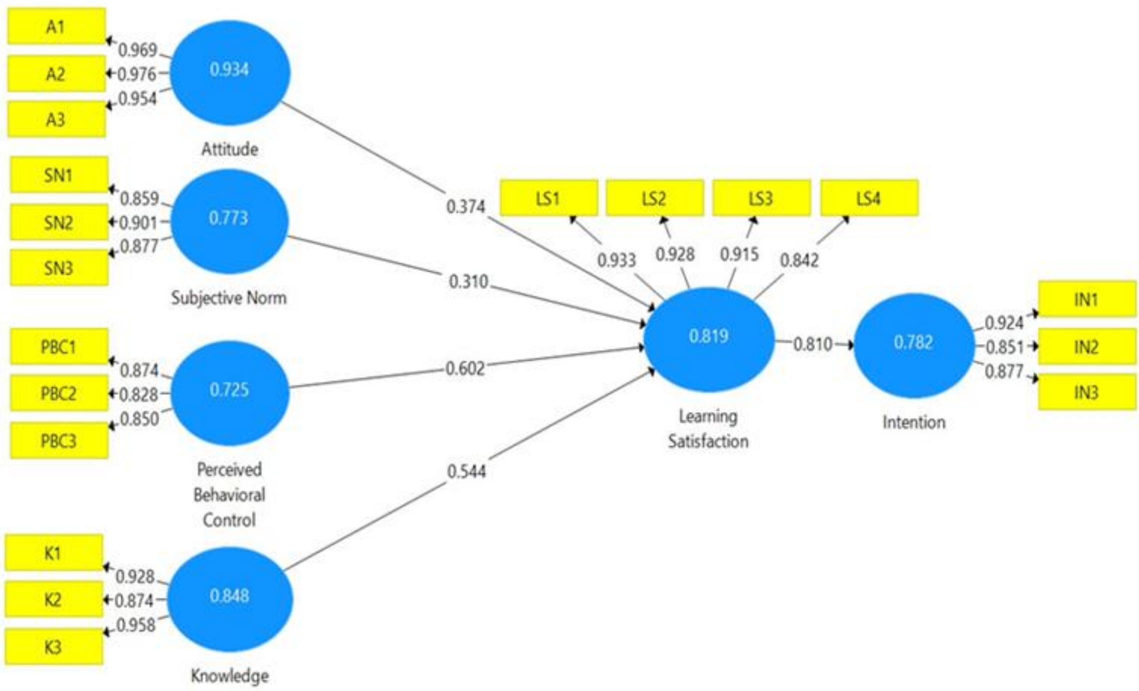

Figure 3: Full model (i.e., inner and outer model) – PLS Algorithm

Measurement Model Assessment

There are two types of measurement models: reflective and formative (Hair et al., 2019; Garson, 2016), each with different criteria (Hair et al., 2019). This study employs the reflective measurement model. When evaluating a reflective measurement model, three criteria should be considered: item loadings, reliability (internal consistency reliability), and validity (convergent and discriminant validity) (Hair et al., 2019).

The first step is to assess the significance of each item's loading, which reflects the reliability of the individual item. Item loadings should meet a threshold of 0.7, with a minimum sample size of 60 cases to ensure adequate significance (Hair et al., 2010). Next is internal consistency reliability, which measures how consistently items within a construct represent that construct. Using Dijkstra-Henseler's rho (ρA) reliability coefficient, values should range from 0.7 to 0.9

(0.7 ≤ ρA ≤ 0.9) to assess internal consistency (Dijkstra & Henseler, 2015). Lastly, validity encompasses both convergent and discriminant validity. Convergent validity is assessed through the Average Variance Extracted (AVE), with a threshold of 0.5, indicating that the reflective constructs explain at least 50% of the variance in their items as highlighted by Hair et al., 2019. Discriminant validity is typically evaluated using the Heterotrait-Monotrait (HTMT) ratio as proposed by Henseler et al., 2015. To confirm discriminant validity, an HTMT value of 0.85 or below is recommended (Kline, 2023). Table 4 provides a summary of the reflective measurement model assessment for this study.

Table 4: Summary of reflective assessment model

Reflective construct (Latent variable)	Reflective indicators (Manifest variables)	Outer loading (>0.70)	Dijkstra-Henseler's rho (pA) (0.7 ≤ pA≥ 0.9)	AVE (>0.50)	HTMT (<0.85)
Attitude (ATT)	ATT1	0.969	0.867	0.934	Yes
	ATT2	0.976			
	ATT3	0.954			
Subjective Norm (SN)	SN1	0.859	0.881	0.773	Yes
	SN2	0.901			
	SN3	0.877			
Perceived Behavioral Control (PBC)	PBC1	0.874	0.879	0.725	Yes
	PBC2	0828			
	PBC3	0.850			
Intention (IN)	IN1	0.924	0.861	0.782	Yes
	IN2	0.851			
	IN3	0.877			
Learning satisfaction (LS)	LS1	0.933	0.827	0.819	Yes
	LS2	0.928			
	LS3	0.915			
	LS4	0.842			
Knowledge (KN)	KN1	0.928	0.824	0.848	Yes
	KN2	0.874			
	KN3	0.958			

Note: AVE is average variance extracted, HTMT is heterotrait-monotrait

As depicted in Table 4 and Figure 3, all reflective indicators have outer loadings above 0.70, demonstrating acceptable item reliability by explaining more than 50% of the indicator's variance. Additionally, Dijkstra-Henseler's rho (ρA) values of 0.867, 0.881, 0.879, 0.861, 0.827, and 0.824 indicate internal consistency reliability. The AVE values of more than 0.50 denote that the construct explains more than 50% of the variance of its items. An HTMT value of less than 0.85 confirms both convergent and discriminant validity.

Structural Model Assessment

The structural model (i.e., the inner model) illustrates the relationships among the latent variables. Figure 4 displays the results from the bootstrapping procedure, which was conducted using criteria such as 5000 bootstrap samples, two-tailed testing, and a significance level of 0.05. Additionally, Table 5 summarizes the path coefficients, t-values, and p-values.

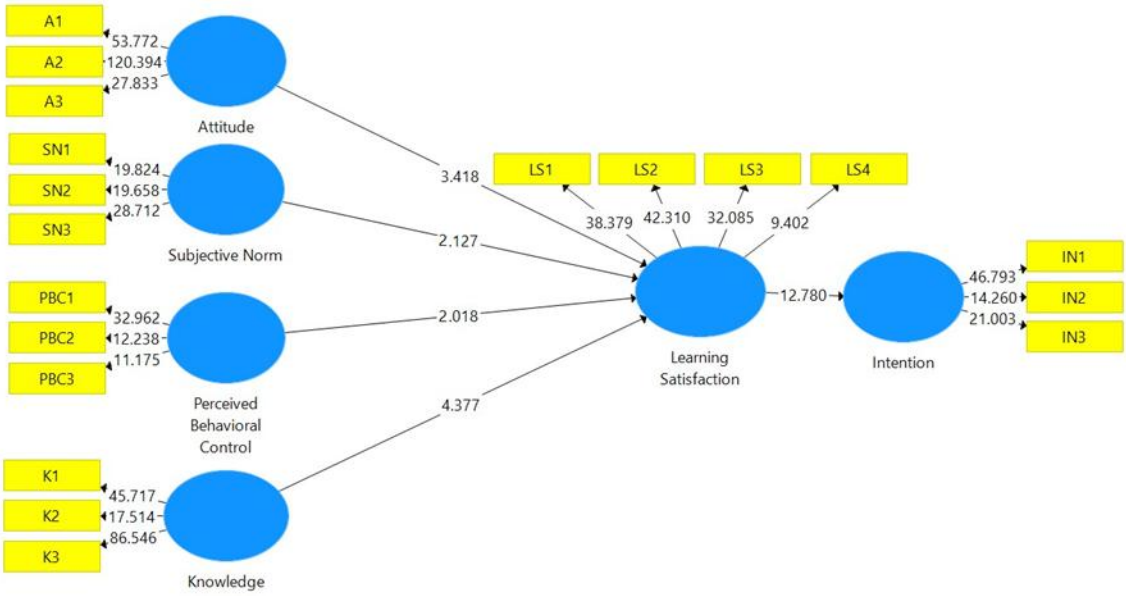

Figure 4: Bootstrapping *t*-value.

Table 5: Summary of structural model path coefficient significance

	t-value (> 1.96)	p-value (<0.05)	Significance	Hypothesis supported?
Attitude → Learning satisfaction	3.418	0.000	Yes	Yes
Subjective norm → Learning satisfaction	2.127	0.006	Yes	Yes
Perceived behavioural control → Learning satisfaction	2.018	0.003	Yes	Yes
Knowledge → Learning satisfaction	4.377	0.000	Yes	Yes
Learning satisfaction → Intention	12.780	0.000	Yes	Yes

Figure 4 and Table 5 indicate that the path coefficients in the inner model were statistically significant, with t-values greater than 1.96 and p-values less than 0.05, as outlined by (Schultz et al., 2014). As a result, all hypotheses, including those related to the first-order relationships, were confirmed. This aligns with the findings of Temel & Cesur, 2024, who asserts that hypotheses are deemed supported when the significance level is 5% or lower ($p \leq 0.05$).

4. Conclusion

The structural equation modelling and data analysis showed a good model fit. The results indicated that the attitude, subjective norm, perceived behavioural control, knowledge of students significantly enhance students learning satisfaction towards Organic Chemistry, which, in turn, strongly influences their intention to use gamification approach during the teaching and learning process. The four factors of the Theory of Planned Behavior (TPB) significantly impact users' pro-sustainability intentions. Additionally, learning satisfaction plays mediating roles in these relationships. This present work advocates that educational gamification can be used as a platform to the student's pro-sustainability intentions in emerging the technology integrated as part of teaching pedagogical. This study suggests that gamification served an effective tool for enhancing students' engagement and learning outcomes in chemistry. By incorporating gamified elements into the learning process, students' understanding of chemistry concepts is improved, as is their overall satisfaction with the learning experience. The findings provide valuable insights for educators and curriculum developers aiming to integrate gamification into their teaching strategies to foster a more interactive and effective learning environment.

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References

Abou Kamar, M., Maher, A., Salem, I. E., & Elbaz, A. M. (2024). Gamification impact on tourists' pro-sustainability intentions: Integration of technology acceptance model (TAM) and the theory of planned behaviour (TPB). *Tourism Review*, *79*(2), 487–504.

Adeshola, I., & Agoyi, M. (2023). Examining factors influencing e-learning engagement among university students during covid-19 pandemic: A mediating role of "learning persistence." *Interactive Learning Environments*, *31*(10), 6195–6222.

Ajzen, I. (1985). *From Intentions to Actions: A Theory of Planned Behavior BT - Action Control: From Cognition to Behavior* (J. Kuhl & J. Beckmann (eds.); pp. 11–39). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-69746-3_2

Arabiat, D., Al Jabery, M., Robinson, S., Whitehead, L., & Mörelius, E. (2023). Interactive technology use and child development: A systematic review. *Child: Care, Health and Development*, *49*(4), 679–715.

Aries, A., Vional, V., Saraswati, L., Wijaya, L., & Ikhsan, R. (2020). Gamification in learning process and its impact on entrepreneurial intention. *Management Science Letters*, *10*(4), 763–768.

Brown, R. (2012). *Pyrolytic methods in organic chemistry: Application of flow and flash vacuum pyrolytic techniques* (Vol. 41). Elsevier.

Denden, M., Tlili, A., Essalmi, F., Jemni, M., Chen, N.-S., & Burgos, D. (2021). Effects of gender and personality differences on students' perception of game design elements in educational gamification. *International Journal of Human-Computer Studies*, *154*, 102674.

Dijkstra, T. K., & Henseler, J. (2015). Consistent partial least squares path modeling. *MIS Quarterly*, *39*(2), 297–316.

Engbers, F. (2023). *The effects of a gamified AR cycling intervention on recreational cyclists' attitude, subjective norm, perceived behavioural control and intention*. University of Twente.

Firipis, A., Chandrasekaran, S., & Joordens, M. (2018). Influence of critical thinking on creativity when using mobile devices for learning. *Asian Education Studies*, *3*(2), 40.

Garson, G. D. (2016). *Partial least squares. Regression and structural equation models*. Statistical Publishing Associates.

Hair, J. F., Black, W. C., & Babin, B. J. (2010). *RE Anderson Multivariate data analysis: A global perspective*. New Jersey, Pearson Prentice Hall.

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, *31*(1), 2–24.

Halford, B. (2016). Is there a crisis in organic chemistry education? Teachers say yes but most of the problems aren't new. *Chemical and Engineering News*, *94*(13), 24–25.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*, 115–135.

Huang, W. H.-Y., & Soman, D. (2013). Gamification of education. *Report Series: Behavioural Economics in Action*, *29*(4), 37.

Jefferies, D. D. L. (2023). *Using gamification to support positive health behaviour change: A kaupapa Māori approach*. The University of Waikato.

Kamalodeen, V. J., Ramsawak-Jodha, N., Figaro-Henry, S., Jaggernauth, S. J., & Dedovets, Z. (2021). Designing gamification for geometry in elementary schools: insights from the designers. *Smart Learning Environments*, *8*(1), 36.

Kline, R. B. (2023). *Principles and practice of structural equation modeling*. Guilford publications.

Leo, J., & Puzio, K. (2016). Flipped instruction in a high school science classroom. *Journal of Science Education and Technology*, *25*, 775–781.

McClary, L. M., & Bretz, S. L. (2012). Development and assessment of a diagnostic tool to identify organic chemistry students' alternative conceptions related to acid strength. *International Journal of Science Education*, *34*(15), 2317–2341.

Motazedian, T., Changizi, M., Kaveh, M. H., & Ghahremani, L. (2024). The Effect of Mothers' Education on Reducing the Aggression of Elementary School Students Using Computer Games: An Application of the Theory of Planned Behavior. *Journal of Research and Health*, *14*(3), 3.

O'Dwyer, A., & Childs, P. E. (2017). Who says organic chemistry is difficult? Exploring perspectives and perceptions. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3599–3620.

Rushton, G. T., Hardy, R. C., Gwaltney, K. P., & Lewis, S. E. (2008). Alternative conceptions of organic chemistry topics among fourth year chemistry students. *Chemistry Education Research and Practice*, *9*(2), 122–130.

Schultz, D., Duffield, S., Rasmussen, S. C., & Wageman, J. (2014). Effects of the flipped classroom model on student performance for advanced placement high school chemistry students. *Journal of Chemical Education*, *91*(9), 1334–1339.

Temel, T., & Cesur, K. (2024). The Effect of Gamification with Web 2.0 Tools on EFL Learners' Motivation and Academic Achievement in Online Learning Environments. *SAGE Open*, *14*(2), 21582440241247930.

Vereijken, M. W. C., & van der Rijst, R. M. (2023). Subject matter pedagogy in university teaching: How lecturers use relations between theory and practice. *Teaching in Higher Education*, *28*(4), 880–893.

Zomer, C., Magee, L., & Third, A. (2021). *Benefits of Recreational Gaming and E-Sports for Young People*.