**Original Research Article**

**ENHANCING GRADE 11 STUDENTS’ ACHIEVEMENT IN PLANT CELL BIOLOGY THROUGH ESCAPE ROOM GAME-BASED LEARNING**

**ABSTRACT**

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| --- |
| The science education in the Philippines has shifted from traditional teacher-centered approach to outcomes-based approached, putting learners at the core of instruction. With this shift, educators must continue to find innovative ways to engage learners into relevant and interactive science instruction. Furthermore, the advent of technology has brought forth a new teaching strategy called Game-Based Learning (GBL), which incorporates technology and games into the delivery of instruction. This one-group quasi-experimental research attempt to test the effects of the Escape Room Game-Based Strategy on students’ achievement in plant cell biology. A total of 25 Grade 11 students from a public school in Davao Occidental, Philippines, participated in the study. Results revealed that the class improved from a “satisfactory” to a “very satisfactory” level in their understanding of plant cell biology. It was found that the Escape Room strategy had a significant effect on the level of science achievement of Grade 11 students. The strategy may be applied to other science topics to assess its effectiveness. This paper also contributes to the growing literature on the effectiveness of game-based learning in teaching science in the Philippines. |

*Keywords: Escape Room Game-Based Strategy, Students’ Achievement, Plant Cell Biology*

**1. INTRODUCTION**

Science is often perceived by students as a difficult subject. As a systematic body of knowledge with varying degrees of content complexity, it is essential to utilize effective teaching strategies to increase student engagement and promote a deeper understanding of the required standards. Considering the global context of education, Philippines is far behind the other countries in terms of quality education specifically in science (Millanes et al., 2017; Rogayan Jr & Dollete, 2019). In the Trends in International Mathematics and Science Study presented by Foy et al., (2013) in their study, the Philippines ranked 34th out of 38 countries and got the 43rd ranked out of 46 countries, respectively when the grade 8 students’ performances in mathematics and science are compared. These results were further supported in the following years with the recent results of the Programme for International Student Assessment (PISA) year 2018 and 2022. In year 2018, Philippines scored an average of 357 points in science, while in 2022, it scored 356 points, indicating consistently poor performance in science across both assessment cycles.

One of the problems experienced by the students is their low mastery of content knowledge in science, specifically in biology. Biology deals with the study of life and its interactions, emphasizing abstract biological concepts and complex processes. Many topics in biology are perceived as difficult to learn, including plant cells and tissues. The structure and functions of plant tissues are regarded as complex due to numerous unfamiliar terms (both Latin and English) and various categories that add to the difficulty. Research in Indonesia by Kusumawati (2016) on the students of SMA Negeri 3 Klaten Class XI during the academic year 2015/2016, students face challenges in learning about the structure and function of plant tissue. These difficulties are influenced by various factors, including students’ motivation toward learning. Therefore, addressing these learning challenges is important as they affect overall academic performance.

Gamification, as an interactive multimedia tool, enables learners to explore and discover deeper scientific principles and phenomena. It is defined as the application of game mechanics into a non-game context to promote students’ engagement and learning (Dominguez et al., 2013). The use of games to facilitate learning is not new, given its significant impact on the learning process. However, with the advent of technology, the scope of the game is improved in creating highly immersive and engaging experience (Dicheva et al., 2015). The integration of ICT in education offers opportunities to make teaching and learning more interactive, transforming the traditional methods into a student-centered approach that focus on active engagement and participation (Villena and Caballes, 2020) of 21st century learners. The purpose of gamification is to develop motivation, comprehension, critical thinking, and improve performance in an enjoyable manner.

The use of gamification is grounded in the Self-Determination Theory by Ryan and Deci (2000), which focuses on intrinsic motivation and identifies three basic psychological needs—autonomy, relatedness, and competence—that, when met, increase students' intrinsic motivation. Learners with high motivation shows a greater interest and participation in the class, resulting in better academic performance. The degree of intrinsic motivation increases with the extent to which these needs are fulfilled. Competence refers to the ability to succeed and overcome obstacles; in gamified systems, leaderboards and badges can foster this sense of expertise. Relatedness is the need to experience connection and belonging, which can be stimulated by collaborative activities. Autonomy is the desire to govern one’s own actions, which can be supported by allowing students to choose from a list of options in a gamified system. Additionally, gamification is anchored in Dewey’s constructivist theory, which views students as active learners who construct their own knowledge, promoting meaningful and lifelong learning. It develops critical thinking and problem-solving skills as learners solves and analyze game levels with varying difficulty and complete tasks to progress. Emphasizing digital literacy in science teaching is essential, as it includes information retrieval skills that help learners navigate diverse sources, nurturing critical thinking and a holistic understanding of the environment (Pedaste et al., 2021). In line with ongoing educational reforms and technological advances, recent research highlights the use of virtual manipulatives in teaching science (Leung & Cheng, 2021; Rutten et al., 2011; Zacharia, 2015). Hsu and Thomas (2002) identified numerous advantages of virtual manipulatives which include handiness, safety, cost efficiency, support in learning, reduced chances of errors, rich multiple representations, and provides fast, dynamic data presentations.

Teaching science to middle school students is considered challenging. According to Alsadoon et. al., (2022), the middle school years are likely among the toughest periods in a student's life. At this point, students experience various physical and mental changes. Assignments become more demanding, and extended study periods are often required. Science, with its abstract or theoretical ideas, can be difficult for many students, and traditional teaching methods often fail to engage or maintain their focus. Consequently, students may lose attention or fail to grasp the material fully, leading to decreased motivation and an increase in least learned competencies, which lowers academic performance. This decline is reflected in local and international science test results. To address this challenge, integrating gamification in education has emerged as a potentially effective strategy. However, gamification is mostly used online, and its effectiveness in offline settings remains underexplored. This research aims to address this gap by examining the effects of offline gamified interventions on science instruction, specifically investigating their impact on students' learning performance.

**2. OBJECTIVES**

The objective of the study is to examine the relationship between Grade 11 students' achievement in plant cell biology and the integration of ICT-based gamification in their science class. Specifically, the study aims to:

1. Determine the impact of ICT-based gamification on students’ academic performance, engagement, and motivation in a structured educational setting.
2. Provide insights into the potential of gamified learning as an effective teaching strategy in science education.
3. Assess whether gamified teaching strategies can positively influence students’ mastery of plant cell biology, leading to a deeper understanding of scientific concepts.

**3. MATERIALS AND METHODS**

**Research Design**

This classroom-based action research employs one-group quasi-experimental design with pre-test and post-test measures to determine the effects of Escape Room Game-Based Strategy on Grade 11 students’ achievement in Plant Cell Biology.

**Research Instrument**

To gather reliable and valid data, the researcher used a teacher-made pre-test and post-test, each consisting of 10 items based on Plant Cell Biology—the identified least-learned competency in the Grade 11 Earth and Life Science subject. These tests were administered before and after the treatment. Additionally, students completed a 5-point Likert scale survey questionnaire to provide feedback on their level of engagement, perceived usefulness, and ease of use of the game-based intervention.

**Respondents of the Study**

The participants of this study were selected through purposive sampling, a non-probability sampling method in which individuals are chosen based on specific traits or attributes relevant to the study’s objectives. The participants consisted of Grade 11 students at Mariano Peralta National High School, Poblacion Malita, Davao Occidental, specifically from the sections handled by one of the researchers. These sections were identified as having the lowest scores on the Plant Cell Biology test in Earth and Life Science during the 2nd quarter of the school year 2024–2025.

**Data Gathering**

The pre-test was conducted to assess the students’ current understanding of Plant Cell Biology before the application of the intervention. This 10-item diagnostic test was administered via Google Forms. Following the pre-test, the Escape Room Game-Based intervention was implemented. A post-test, consisting of a parallel quiz, was administered after the intervention to evaluate any improvements in the students’ understanding of Plant Cell Biology. The post-test mirrored the pre-test to allow for direct comparison of results. Additionally, student feedback was collected through a survey to gain insights into their experiences and perceptions of the escape room strategy.

The researchers utilized the Escape Room Game-Based strategy as the intervention over the course of one week. This quasi-experimental study was conducted from May 5 to 9, 2025. This teaching strategy is both cognitive and intrinsic, recognizing, and motivating students’ efforts in accomplishing each task and challenge within the game.

Table 1. Procedure for Implementing Escape Room Game in Class

|  |  |
| --- | --- |
| **DAY** | **ACTIVITY** |
| 1 | Measurement of conceptual understanding (Pre-test) |
| 2 | Implementation of Escape Room Game Based Strategy |
| 3 |
| 4 |
| 5 | Measurement of conceptual understanding (Post-test) and Student Feedback (Survey) |

Table 2. Score Interpretation in Pretest and Posttest

|  |  |  |
| --- | --- | --- |
| **Scores** | **Abbreviation** | **Verbal Description (VD)** |
| 9-10 | O | Outstanding |
| 7-8 | VS | Very Satisfactory |
| 5-6 | S | Satisfactory |
| 3-4 | FS | Fairly Satisfactory |
| 1-2 | DNME | Did Not Meet Expectations |

Table 3. 5-point Likert Scale Interpretation

|  |  |  |
| --- | --- | --- |
| **Score Range** | **Mean Rating** | **Interpretation** |
| 4.21 – 5.00 | Strongly Agree | Very Positive |
| 3.41 – 4.20 | Agree | Positive |
| 2.61 – 3.40 | Not Sure | Moderate |
| 1.81 – 2.60 | Disagree | Negative |
| 1.00 – 1.80 | Strongly Disagree | Very Negative |

**4. RESULTS AND DISCUSSION**

**Students’ Level of Achievement in Plant Cell Biology Before the Treatment**

A 10-item pre-test was administered to assess the level of achievement of Grade 11 students in plant cell biology. The pre-test result was tabulated to determine the level of achievement of Grade 11 students prior to the application of the game-based intervention (Table 4).

Table 4. Distribution of Students’ Scores in Pretest

|  |  |  |
| --- | --- | --- |
| **Pre-Test Scores** | **Frequency** | **Percent** |
| 9 - 10 | 2 | 8.00 |
| 7 - 8 | 7 | 28.00 |
| 5 - 6 | 11 | 44.00 |
| 3 - 4 | 5 | 20.00 |
| Total | 25 | 100 |
| **Weighted Mean 6.00 (Satisfactory)** |

The results of the pre-test showed that students’ conceptual understanding of Plant Cell Biology was at a satisfactory level, as indicated by a weighted mean of 6.00 (SD = 1.59). The test scores were mostly concentrated in the range of 5 to 6 out of the 10 items on the pre-test. Before the implementation of the game-based intervention, the level of achievement of Grade 11 students in Plant Cell Biology was considered satisfactory based on the weighted mean.

 The use of gamification is anchored in the Self-Determination Theory by Ryan and Deci (2000), which is particularly effective because it focuses on intrinsic motivation and taps into the learner’s interests. According to Ding and Yu (2024), students with low motivation often exhibit poor performance in science. Game-based learning has been suggested as a potential solution to this problem by engaging students and motivating them to learn science interactively. The use of the Escape Room Game-Based Strategy allows learners to engage more effectively in the actual teaching-learning process.

**Students’ Level of Achievement in Plant Cell Biology After the Treatment**

A post-test was conducted through a parallel quiz after the intervention to evaluate any improvements in the students’ conceptual understanding of plant cell biology.

Table 5. Distribution of Students’ Scores in Posttest

|  |  |  |
| --- | --- | --- |
| **Post-Test Scores** | **Frequency** | **Percent** |
| 9 - 10 | 14 | 56.00 |
| 7 - 8 | 10 | 40.00 |
| 5 - 6 | 1 | 4.00 |
| Total | 25 | 100 |
| **Weighted Mean 8.52 (Very Satisfactory)** |

Post-test result shows that none of the students belonged to did not meet expectations and satisfactory level. The bulk of the test scores was in the bracket of 9 to 10 with 14 students (56%). With the weighted mean of 8.52 (SD = 1.12) and was classified as Very Satisfactory level after the use of escape-room game-based strategy.

Several studies have confirmed that game-based learning strategies, such as the instructional tool developed in this study, are effective pedagogies for teaching science concepts. According to Adipat et al. (2021), games can motivate students to apply both their prior knowledge and newly acquired knowledge from different disciplines in their decision-making processes, allowing them to test how their choices affect the outcomes within the game.

To easily compare the mean score of pretest and posttest, a graph is presented in Figure 1.



Figure 1. Mean Comparison of Pretest and Posttest Scores

As shown in Figure 1, the results of the pre and posttest indicate that the scores were notably higher after the intervention. Grade 11 students answered more question correctly, with the mean increasing from 6.000 to 8.520. This suggests an improvement in students’ science achievement in Plant Cell Biology. Moreover, the standard deviation before the intervention was 1.528, indicating a wider range of knowledge as the scores were more spread out. After the intervention, the standard deviation decreased to 1.122, showing that students’ knowledge became more consistent and that most students had a similar level of understanding. A smaller standard deviation in the post-test generally suggests that the game-based strategy was effective in improving students’ science achievement in Plant Cell Biology.

**Difference in the Level of Students’ Achievement on Plant Cell Before and After the Treatment**

To determine whether the data follow a normal distribution, a Shapiro-Wilk test was conducted, as shown in Table 6.

| Table 6. Test of Normality  |
| --- |
|   |   |   | W | p |
| Pre-test Plant Cell |  | - |  | Post-Test Plant cell |  | 0.911 |  | 0.032 |  |
|  |
|  |

The p-value for both pretest and posttest is 0.032. This suggests that the test scores before and after the test is not perfectly following a standard bell curve. Thus, a Wilcoxon Signed-Rank test which is a non-parametric statistical tool be used to test if there is a significant difference between the two variables (Table 7).

| Table 7. Wilcoxon-Signed Rank Test of the Pretest and Posttest  |
| --- |
| Measure 1 |   | Measure 2 | W | z | df | p |
| Pre-test Plant Cell |  | - |  | Post-Test Plant cell |  | 0.000 |  | -4.107 |  |  |  | < .001 |  |
|  |
|  |

Using the Wilcoxon Signed-Rank test for paired samples, the computed p-value was 0.001, indicating a significant difference between the test scores before and after the intervention. The increase in the average score (from 6.00 to 8.52) is very likely a true effect of the intervention rather than a result of random chance. Furthermore, the results suggest that the intervention led to a significant improvement in the students’ science achievement in Plant Cell Biology following the use of the Escape Room Game-Based Strategy.

The findings of this study support previous research on the use of digital game-based learning to enhance students’ academic performance (Wang et al., 2022). Cetin-Dindar and Geban (2016) found that students were more motivated to learn when using interactive strategies compared to traditional teacher-centered approaches. Moreover, the diverse learning characteristics of students and the advancement of technology make it necessary for teachers to implement a wide variety of interactive activities and lessons in their classrooms.

**Student Perception Survey of Escape-Room Game-Based Strategy Level of Engagement**

To examine how digital game-based learning improves the science achievement of Grade 11 students in Plant Cell Biology, a 5-point Likert scale survey questionnaire was used. The questionnaire was divided into three parts: level of engagement, perceived usefulness, and ease of use.

Table 8. Mean Scores of Levels of Engagement

|  |
| --- |
|   | Valid | Missing | Mean | Std. Deviation |
| 1.1 The game made learning about plant cell organelles more interesting. |  | 25 |  | 0 |  | 4.560 |  | 0.507 |  |
| 1.2 I enjoyed playing the game more than traditional textbook learning. |  | 25 |  | 0 |  | 4.200 |  | 0.645 |  |
| 1.3 The game kept me motivated to learn about cell organelles. |  | 25 |  | 0 |  | 3.920 |  | 0.572 |  |
| 1.4 I would like to use similar games for other biology topics. |  | 25 |  | 0 |  | 4.480 |  | 0.510 |  |
|  **Weighted Mean** **4.29** **(Very Positive)** |

The results showed that, on average, students strongly agreed that the game made learning more interesting, with a mean response of 4.56. While engagement was generally high, motivation to learn about cell organelles (Mean = 3.92) scored slightly lower, possibly due to game mechanics or content depth. Overall, students enjoyed learning about plant cell organelles through the game, as evidenced by an average mean of 4.29. This indicates minimal disagreement among students and reflects a very positive attitude toward using the game for learning.

According to Al-Khayat et al. (2023), the use of game-based learning positively influences students’ engagement and motivation by providing an interactive learning environment that enhances decision-making, critical thinking, and problem-solving skills. Game-based learning also improves students’ attention (Jääskä et al., 2022), making them more focused on learning the concepts. Furthermore, Nadeem et al. (2023) emphasized that incorporating game-based activities into lectures can create an enjoyable and engaging experience. Therefore, designing game-based instruction requires careful attention to crafting games that are relevant, interactive, and provide meaningful feedback to ensure positive learning outcomes.

**Student Perception Survey of Escape-Room Game-Based Strategy Perceived Usefulness**

To assess students’ beliefs about how game-based learning can improve their conceptual understanding of Plant Cell Biology, the mean scores for perceived usefulness are presented in Table 9.

| Table 9. Mean Scores on Perceived Usefulness |
| --- |
|   | Valid | Missing | Mean | Std. Deviation |
| 2.1 The game helped me understand the functions of plant cell organelles better. |  | 25 |  | 0 |  | 4.280 |  | 0.542 |  |
| 2.2 I can recall organelle names and roles more easily after playing the game. |  | 25 |  | 0 |  | 3.920 |  | 0.702 |  |
| 2.3 The game improved my performance in quizzes/tests about plant cells. |  | 25 |  | 0 |  | 4.200 |  | 0.577 |  |
| 2.4 The game was an effective tool for reviewing lesson content. |  | 25 |  | 0 |  | 4.400 |  | 0.500 |  |
| **Weighted Average 4.20 (Very Positive)**  |
|  |

The Grade 11 students strongly agreed that the intervention was useful for learning Plant Cell Biology, with an average rating of 4.20. However, students felt that the game helped them understand organelle functions (Mean = 4.28) more than it helped with recall (Mean = 3.920). This indicates that the game’s design emphasized conceptual learning over memorization. Overall, the results indicate that the tool was highly effective for reviewing content and enhancing students’ understanding of plant cells.

 The study of Zhang (2024) reveals that there is a direct relationship between perceived usefulness and technology on education in the academic performance of the students. This could be attributed to utilization of technological tools such as game-based learning leading to a deeper understanding of the topic. Additionally, students feel more motivated to learn if the game has a fun element (Udeozor et al., 2023) as an add on factor that the game should be relevant to their learning.

**Student Perception Survey of Escape-Room Game-Based Strategy Ease of Use**

Games that are easy to understand and navigate are more likely to keep students actively involved and engaged in the learning process. The mean score for the ease of use of the Escape Room Game-Based Strategy is presented in Table 10.

Table 10. Mean Scores on Ease of Use

|  |
| --- |
|   | Valid | Missing | Mean | Std. Deviation |
| 3.1 The game was easy to navigate. |  | 25 |  | 0 |  | 4.000 |  | 0.707 |  |
| 3.2 The instructions were clear and easy to follow. |  | 25 |  | 0 |  | 4.560 |  | 0.507 |  |
| 3.3 I did not experience technical difficulties while playing. |  | 25 |  | 0 |  | 4.000 |  | 0.577 |  |
| 3.4 The game's design (colors, layout, etc.) was user-friendly. |  | 25 |  | 0 |  | 4.280 |  | 0.614 |  |
|  **Weighted Average 4.21 (Very Positive)** |

The results showed that students found the game very easy to use, with an overall mean score of 4.21. The highest-rated item was the clarity of instructions (Mean = 4.56), indicating that students had no trouble understanding how to play the game. However, two areas scored slightly lower (Mean = 4.00): ease of navigation and technical issues. This suggests that while most students could use the game without difficulty, a few may have encountered minor challenges navigating the game.

 In the study by Zainuddin (2023), gamification-based activities were found to increase students’ attention and enthusiasm, leading to improved learning outcomes. Moreover, he noted that easy-to-use digital platforms significantly enhanced student engagement during the learning process. Additionally, Cheung and Ng (2021) found that students, as digital natives, find it easy to play educational games, especially on mobile devices. This ease of use contributes to the growing popularity of educational games.

**5. CONCLUSIONS AND RECOMMENDATIONS**

**Conclusion**

The study aims to ascertain the effects of Escape Room Game-Based Strategy in enhancing the Grade 11 students’ mastery of plant cell structures and functions. Before the intervention, the students were performing satisfactorily in terms of their understanding of plant cell organelles. After the intervention, there was a significant improvement in the students’ level of mastery. The higher mean score following the implementation of the Escape Room Game-Based strategy suggests that this approach may enhance students’ mastery of plant cell structures and functions. The teacher-implementer observed that using game-based learning for science concepts enhances students’ understanding and improves learning outcomes.

The use of the Escape Room Game-Based teaching strategy had a significant impact on the mastery of plant cell biology among Grade 11 students, as demonstrated by the study’s results. The purpose of the intervention was to improve the students’ mastery of plant cell biology, which was clearly reflected in their pretest and posttest scores. This was further validated by the students’ feedback regarding the game, particularly in terms of their level of engagement, perceived usefulness, and ease of use. Furthermore, the pedagogical strategy employed by the teacher enhanced the students’ intrinsic motivation, critical thinking, and decision-making skills.

**Recommendation**

The recommendations of this study are for science teachers to utilize the Escape Room Game-Based strategy to improve the mastery of students on plant cell structures and functions. Teachers can also employ the concept and use it to address other least learned competency in science. They may further localize and contextualize the learning tasks to suit the needs of their students. School heads may include the Escape Room Game basic principles in conducting learning action cell (LAC) for science teachers to familiarize themselves with the basics of Escape Room Game which is based of Game-Based Learning. Students may work in teams or partner in playing the game to make it more cooperative and collaborative. Future research may be conducted by other teacher-researcher to validate the effects of the intervention in improving the mastery of students on plant cell structures and functions. Since the present study only involved one group, further studies may involve two groups, which will serve as the control group and experimental group for better comparison.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**REFERENCES**

Adipat, S., Laksana, K., Busayanon, K., Ausawasowan, A., & Adipat, B. (2021). Engaging students in the learning process with game-based learning: The fundamental concepts. *International Journal of Technology in Education, 4*(3), 542–552. https://doi.org/10.46328/ijte.169

Al-Khayat,M. R, Gargash, Maha U., & Atiq,A. F. (2023). The effectiveness of game-based learning in enhancing students’ motivation and cognitive skills. *Journal of Education and Teaching Methods, 2*(3), 50–62. Retrieved from https://gprjournals.org/journals/index.php/jetm/article/view/199

Alsadoon, E., Alkhawajah, A., & Suhaim, A. B. (2022). Effects of a gamified learning environment on students’ achievement, motivations, and satisfaction. Heliyon, 8(8).

Cetin-Dindar, A., & Geban, O. (2016). Conceptual understanding of acids and bases concepts and motivation to learn chemistry. *The Journal of Educational Research, 110*(1), 8597. https://doi.org/10.1080/00220671.2015.1039422\

Cheung, S. Y., & Ng, K. Y. (2021). Application of the educational game to enhance student learning. Frontiers in Education, 6. https://doi.org/10.3389/feduc.2021.623793

Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in education: A systematic mapping study. *Educational Technology & Society, 18*(3), 75–88. http://www.ifets.info/journals/18\_3/6.pdf

Ding, A. E., & Yu, C. (2024). Serious game-based learning and learning by making games: Types of game-based pedagogies and student gaming hours impact students’ science learning outcomes. *Computers & Education*, 218, 105075. https://doi.org/10.1016/j.compedu.2024.105075

Domínguez, A., Saenz-de-Navarrete, J., De-Marcos, L., Fernández-Sanz, L., Pagés, C., & Martínez-Herráiz, J. J. (2013). Gamifying learning experiences: Practical implications and outcomes. *Computers & education*, 63, 380-392.

Foy, P., Arora, A., & Stanco, G. M. (2013). TIMSS 2011 user guide for the international database. ERIC. https://timssandpirls.bc.edu/timss2011/downloads/T11

Hsu, Y., & Thomas, R. A. (2002). The impacts of a web-aided instructional simulation on science learning. *International Journal of Science Education, 24*(9), 955–979. https://doi.org/10.1080/09500690110095258

Jääskä, E., Lehtinen, J., Kujala, J., & Kauppila, O. (2022). Game-based learning and students’ motivation in project management education. *Project Leadership and Society*, 3, 100055. https://doi.org/10.1016/j.plas.2022.100055

Kusumawati, M. U. (2016). IdentifikasiKesulitan Belajar Materi Struktur -Fungsi Jaringan Tumbuhan pada SiswaSMA Negeri 3 Klaten kelas XI TahunAjaran 2015/2016. *Jurnal PendidikanBiologi, 5* (7), 19–26. (PDF) High school biology topics that perceived difficult by undergraduate students. Available from: https://www.researchgate.net/publication/329939200\_HIGH\_SCHOOL\_BIOLOGY\_TOPICS\_THAT\_PERCEIVED\_DIFFICULT\_BY\_UNDERGRADUATE\_STUDENTS [accessed May 30 2025].

Leung, P. K., & Cheng, M. M. (2021). Practical work or simulations? Voices of millennial digital natives. *Journal of Educational Technology Systems, 50*(1), 48–72. https://doi.org/10.1177/00472395211018967

Millanes, M. A. A., Paderna, E. E. S., & Que, E. N. (2017). Podcast integrated physics teaching approach: Effects on student conceptual understanding. *The Normal Lights, 11*(2), 6085. https://po.pnuresearchportal.org/ejournal/index.php

Nadeem, M., Oroszlanyova, M., & Farag, W. (2023). Effect of digital game-based learning on student engagement and motivation. *Computers, 12*(9), 177. https://doi.org/10.3390/computers12090177

Pedaste, M., Kalmus, V., & Vainonen, K. (2021). Digipädevuse dimensioonid ja nende hindamine põhikoolis. Dimensions of digital literacy and their assessment in primary schools. Eesti Haridusteaduste Ajakiri. *Estonian Journal of Education, 9*(2), 212-243.

PISA 2022 Results (Volume I). (2023). In Programme for international student assessment/Internationale Schulleistungsstudie. https://doi.org/10.1787/53f23881-en

Rogayan, D. V., Jr, & Dollete, L. F. (2019). Development and validation of physical science workbook for senior high school. *Science Education International, 30*(4), 84–290. https://doi.org/10.33828/sei.v30.i4.5

Rutten, N., Van Joolingen, W. R., & Van Der Veen, J. T. (2011). The learning effects of computer simulations in science education. *Computers & Education, 58*(1), 136–153. https://doi.org/10.1016/j.compedu.2011.07.017

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066x.55.1.68

Udeozor, C., Russo-Abegão, F., & Glassey, J. (2023). Perceptions and factors affecting the adoption of digital games for engineering education: a mixed-method research. *International Journal of Educational Technology in Higher Education, 20*(1). https://doi.org/10.1186/s41239-022-00369-z

Villena, R. R., & Caballes, D. G. (2020). Integration of information communication technology in teaching science technology and society. *CiiT International Journal of Data Mining and Knowledge Engineering, 12*(2), 34–38. https://www.ciitresearch.org/dl/index.php/dmke/article/view/DMKE022020004.

Wang, L., Chen, B., Hwang, G., Guan, J., & Wang, Y. (2022). Effects of digital game-based STEM education on students’ learning achievement: a meta-analysis. *International Journal of STEM Education, 9*(1). https://doi.org/10.1186/s40594-022-00344-0

Zacharia, Z. C. (2015). Examining whether touch sensory feedback is necessary for science learning through experimentation: A literature review of two different lines of research across K-16. *Educational Research Review*, 16, 116–137. https://doi.org/10.1016/j.edurev.2015.10.001

Zainuddin, Z. (2023). Integrating ease of use and affordable gamification-based instruction into a remote learning environment. *Asia Pacific Education Review, 25*(5), 1261–1272. https://doi.org/10.1007/s12564-023-09832-6

Zhang, F. (2024). Effects of game-based learning on academic outcomes: A study of technology acceptance and self-regulation in college students. *Heliyon*, *10*(16), e36249. https://doi.org/10.1016/j.heliyon.2024.e36249