Gamification of Science Learning: Perspectives on Developing Students' Scientific Attitudes

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Abstract. The learning environment must be designed to motivate students to acquire scientific knowledge while developing their scientific attitude. As essential learning for students, science learning must be responsive to this by facilitating the development of students' scientific attitudes. Gamification is an effort to spark interest, spur motivation, and encourage student engagement in the learning process. Much research on gamification has been done by adopting game mechanics and aesthetics in learning and has generally succeeded in improving student learning outcomes. However, the relationship between using gamification in learning and improving students' scientific attitudes has not been widely studied and discussed in theory. Therefore, this paper presents a literature review of fields in which gamification can intervene to improve students' scientific attitudes.

Keywords: gamification; science learning; scientific attitude

INTRODUCTION

Throughout history, science has had tremendous authority and prestige because it has always succeeded in maintaining its existence as knowledge to explain how nature works [1]. Considering the importance of this knowledge, everyone should have a good understanding of science because it will be beneficial throughout their lives. Legendary scientists such as Galileo, Newton, Darwin, and Einstein have provided profound insights about the universe. They passed on a lot of knowledge to humanity. Scientists' character can take many things. Besides their wisdom, the vital thing we can take from scientists is their scientific attitude. Author [2] states that attitude comes from the Latin "aptitudo", which means ability, so attitude can be interpreted as a reference to one's ability to do specific jobs. Attitude measures the preferences and feelings the subject expresses towards an object [3]. The scientific attitude is essential for students because it reflects the attitude and character of scientists. The scientific attitude in science learning is a person's tendency to solve problems about nature and daily life by using scientific methods such as observation and experimentation to instil an attitude of curiosity, not giving up easily, coopera-

tion, openness, responsibility, and critical thinking.

Learning fun science starts from a sense of interest in learning. Current learning needs to be focused on improving specific technical skills, new ways of thinking, and different learning approaches [4]. One approach that fits the characteristics of 21st-century learning is gamification, or using game elements in education [5]. This paper describes gamification as an effort to arouse students' interest and motivation in learning science. One of the things that can be done to trigger motivation is using game design elements, game mechanics, aesthetics, and game thinking in non-game fields [6]. Gamification is a game thinking technique and mechanism to improve non-game contexts [7]; in this case, the non-game context is a learning process. The idea behind the logic of gamification is the transferable motivational power of game elements in educational contexts [8]. Gamification in science learning can enrich and facilitate learning by adopting game designs, components, and mechanics. The relationship between the use of gamification and the improvement of students' scientific attitudes in education has not been much discussed in theory. A theoretical study that can be intervened in gamification so it can

increase students' scientific attitudes is essential to review. Therefore, writing this article tries to reveal it.

METHOD

This paper is a literature review of the relationship between the use of gamification and the development of students' scientific attitudes. The first steps in any research are finding, selecting, considering, and reading literature [9]. The literature review was conducted on the awareness that the knowledge and analysis carried out by people worldwide continue to grow. Research topics, samples, and areas or fields of study are likely to have been penetrated by others before so that researchers can learn from things that have been done [10]. The primary purpose of the literature review is twofold: first, to introduce new studies in a particular topic that need to be known by those who are involved in the case of science, and second, to relate to the importance of the research project itself, which is to enrich insight into the research topic [11]. The writing of this literature review paper refers to the second point. The literature in this paper was found with the Publish or Perish search engine with the search area "Scopus" with the keyword "gamification science attitude" restricted from 2019-2023. From a total of 43 lists of articles that appeared, articles were selected and considered by the field of science and full access. Next, the selected papers were read and reviewed for supporting studies.

RESULTS AND DISCUSSION

Science education is one of the most essential parts of the education system because it creates the next generation with the knowledge, character, and skills needed in this 21st century and the future. Author [12] suggests some of the main problems that need to be addressed for sustainable and adequate science education are: lack of student motivation and low levels of confidence in learning, persistent achievement gaps in science and mathematics among many subgroups of students, inadequate physical condition of schools (lack of opportunities for laboratory practice), intensive curriculum but insufficient time allocation for learning science, students are generally in a passive position (only listening and writing) while teachers are in an active role (writing on the board and teaching classically).

These problems are seen to affect students' attitudes towards science at school.

Concerning student attitudes, science learning in schools should be designed to develop scientific attitudes, which are the characteristics of scientists. Attitudes in science are divided into two: the attitude of science (scientific attitude) and the attitude towards science. Science attitude and attitude toward science are two different things. First, a scientific attitude is an attitude possessed by a person to solve problems systematically according to scientific steps. This scientific attitude is the desire to know and understand, to question all statements, to seek data and their meaning, to seek verification, and to consider consequences [3, 13]. The scientific attitude in science learning is a person's tendency to solve problems related to nature and daily life using scientific methods such as observation and experimentation to instil an attitude of curiosity, not easily discouraged, cooperation, open attitude, responsibility, and critical thinking. The American Association for the Advancement of Science (AAAS) emphasizes four attitudes for elementary school students: honesty, curiosity, open-mindedness, and scepticism.

Second, attitude toward science is a feeling, belief, and view of science, science learning, scientists, and the impact of science and technology on society. The author [14] defines science as a set of affective behaviours in science learning that are manifestations of a good attitude towards science and scientists, acceptance of scientific inquiry as a way of thinking, adoption of a scientific attitude, enjoyment in learning science, development interest in science and science-related activities, and development interest in pursuing a career in science or science-related work. Students' positive attitude towards science is a critical attitude to develop. The author [15] developed the Test of Science-Related Attitude, which is used to measure students' attitudes towards science in the form of 70 items with seven subscales: social implications of science, normality of science, attitudes towards scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. Students' positive attitudes towards science should be a primary concern for teachers because it affects students' views and participation in science classes. The author [16] states that students' positive attitudes towards science are closely related to increased interest in science learning and science

process skills. Students with a positive attitude will show increased attention to classroom learning and more participation in science activities [17, 18].

The attitude discussed in this paper is the attitude of students toward science. According to [15] in TOSRA (Test of Science Related Attitude), one subscale of the assessment of attitudes towards science is the interest in a science career. This subscale has been highlighted in many studies over time and reveals that there has been a decline in student interest in pursuing careers in science [3, 19, 20]. Some researchers connected that condition to a general decline in science interest among high school students [21, 22]. Students' interest in science from age 14 will carry over into adulthood. The age of 11 to 14 years is the best period to encourage increased interest in science learning and determine their future career [23]. The age of 11 to 14 years is the golden age in determining students' attitudes toward science, which takes place in elementary school phase C until the end of junior high school. Authors [24] claim that it is necessary to conquer the decline in positive attitudes toward science by improving students' views on science from the early grades of elementary school.

Students in elementary school generally have difficulty understanding abstract concepts. The conceptual ideas interfere with students' understanding of the content and negatively affect their attitudes toward related subjects [25]. Authors [26] state that students with negative attitudes towards difficult or tedious topics can change their attitudes by using digital games to make learning easy and fun. Games in learning have increased and can be adopted in various fields of education, including science learning. Game learning is believed to improve students' ability to learn multiple things and increase effectiveness, job efficiency, cooperation, and a positive attitude [27]. Authors [28] revealed that using games in learning positively impacted the classroom experience and improved students' attitudes toward science.

Gamification is a pedagogical strategy that introduces the principles of the game in a learning environment by promoting participation and increasing motivation. Authors [5] define gamification as adopting game elements into non-game contexts. This paper's gamification of science learning uses game elements to motivate the students to learn. The core idea of gamification in education is game mechanics to enrich and facilitate learning. The literature shows that their motivation increases significantly when students engage in an enjoyable learning experience compared to usual learning activities. Learning in a distraction-free atmosphere helps students cultivate a positive attitude toward learning because they can learn and participate in learning at their own pace, free from peer and teacher pressure [29]. The development of gamification today focuses a lot on students' digital engagement by using platforms in digital devices such as tablets, smartphones, or computers [30]. All gamification apps have two goals: first, learning objectives that match the content, and second, fun goals related to the expected user experience [31]. Hence, a more meaningful learning environment can be designed where increased achievement and positive attitude development can be expected.

Authors [32] highlight gamification in learning as an effort to influence students' psychological factors to mediate learning outcomes. The application of gamification in education intervenes in three main areas of the individual: cognitive, emotional, and social [33]. First, in the mental area, the experience of playing in a gamification system that students explore will indirectly raise the students' efforts in learning more to stay engaged in the game. The author [34] shows that the degradation of students' attitudes toward science occurs because the topics in science class are not related to student's preferences, interests, and contexts of daily life. On the other hand, authors [35] state that students' negative attitudes toward science are related to traditional approaches to learning, while students' positive attitudes toward science are related to constructivist learning. Success in the use of conventional learning approaches as well as constructivist learning depends on students' willingness to learn. Gamification can facilitate the realization of a learning environment that motivates students to learn, even unconsciously, because they are busy following the game's flow. The game system will guide students to master potentially complex tasks in-game learning [36].

Moreover, gamification accommodated by information computers and technology (ICT) can contribute significantly to student motivation [37, 38, 39]. Gamification with technology can motivate students' learning because the human brain processes visuals faster than text. When students have been in a state of "flow" in the sci-

ence learning game, they unconsciously acquire scientific knowledge while choosing a positive attitude towards science learning. Authors [40] found gamification's effectiveness in developing motivation and learning attitudes. Therefore, gamification can act as a place to foster students' interest, motivation, and positive attitudes to learning science better.

Second, in the emotional area, gamification raises various strong emotions, such as optimism and pride [41] and curiosity and excitement [42]. These forms of emotion can affect students' behaviour/attitudes toward learning. On the other hand, this emotion is closely related to motivation since it is an individual psychological condition. This causes stimulation and can also affect student behaviour/attitudes toward learning. High motivation synergizes with a positive attitude, such as increased effort, perseverance, and improved performance [43]. Authors [44] state that motivation and a positive attitude are needed to achieve a successful learning experience. Students with a positive attitude and high motivation will be more successful than their peers [45]. Highly motivated learners with positive attitudes tend to generate opportunities for activity engagement [46]. Student engagement in science learning activities is one of the forms of a positive attitude toward science. In this case, gamification can increase motivation, problem-solving skills, and cooperation [47, 48, 49] and encourage student learning [6]. A satisfactory sense and achievement in learning will upgrade students' capacity to solve problems and increase their independence and learning motivation [50]. Gamification in education can make students survive and even be able to turn negative emotional experiences into positive ones. When engaging in a learning game, students face the chance of winning and losing, such as two sides of a coin. The author [51] states that game learning makes students always learn because the only way to learn how to play is to experience losing first. Through gamification, students will learn that losing is not a reason to give up but instead learning to achieve winning [4]. Therefore, gamification can direct students' attitudes to be more positive in viewing losing as an essential part of learning and more motivated to achieve winning and successful learning.

In the social area, gamification can provide opportunities for students to try new identities or roles and make decisions from a unique point of view [51, 52]. Authors [53] revealed that social factors are significantly related to students' attitudes toward science: gender, socioeconomic status, and teacher-student relationships. Gender is the most significant variable in students' attitudes toward science [13, 24, 54, 55, 56, 57]. Male students with better socioeconomic status and better teacher-student relationships had more positive attitudes toward science [53]. One of the goals of science education is to develop a positive attitude toward science regardless of individual differences [58], so a positive attitude towards science should be developed in both male and female students. Several other studies have also shown that classroom learning environments strongly determine students' attitudes toward science [59, 60, 61, 62]. In line with this, the author [63] also suggests that the ability of science teachers and schools has a significant role in developing scientific students' attitudes and encourages them to build their interest and tendency toward science. In other words, the science learning environment in class correlates with students' attitudes toward science. In response to these various social factors, gamification systems can provide a constructive and socially interactive learning environment [64], safe and natural for students to experiment without harm [65], and also offer social credibility and recognition of academic achievement that may not be seen or even denigrated by other students [33]. Integrating gamification in learning can increase engagement, excitement, and motivation [66]. In the future, students will become more receptive and accustomed to engaging in similar gamification learning environments [8]. Therefore, various problems and difficulties in learning science, especially related to students' attitudes toward science, can be fostered through gamification.

CONCLUSIONS

Gamification in learning will make the learning atmosphere more enjoyable, encourage students to complete their learning activities well, help students focus more on understanding the science topics, and give them opportunities to compete, explore, and excel in class. Based on the literature review, gamification is seen as developing student attitudes through three main areas in which gamification can intervene. First, in the cognitive area, gamification can act as a place to foster students' interest, motivation, and positive attitudes to learn the subject matter better. Sec-

ond, in the emotional area, gamification brings out a variety of strong emotions, such as curiosity and excitement, that can influence students' behaviour/attitudes towards learning. Gamification in education can direct students' attitudes to be more positive in viewing failure as an essential part of learning and more motivated to achieve success in the learning process. Third, in the social area, gamification provides a constructive and socially interactive learning environment that will increase students' positive attitudes toward science. This literature review article has revealed that gamification of science learning can be done as an effort to develop students' scientific attitudes.

REFERENCES

1. Dear, P. (2006). *The Intelligibility of Nature: How Science Makes Sense of the World*. Chicago: University of Chicago Press.

2. Çalışkan, H., & Kılınç, G. (2012). The Relationship Between the Learning Styles of Students and Their Attitudes Towards Social Studies Course. *Procedia - Social and Behavioral Sciences, 55*, 47–56. doi: 10.1016/j.sbspro.2012.09.476

3. Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. doi: 10.1080/0950069032000032199

4. McGrath, N., & Bayerlein, L. (2013). *Engaging online students through the gamification of learning materials: The present and the future*. Retrieved from https://www.researchgate.net/publication/262223845_Engaging_online_students_through_the_gamification_of_learning_materials_The_present_and_the_future

5. Deterding, S., Sicart, M., Nacke, L., O'Hara, K., & Dixon, D. (2011). Gamification. using game-design elements in non-gaming contexts. *CHI '11 Extended Abstracts on Human Factors in Computing Systems*. doi: 10.1145/1979742.1979575

6. Kapp, K. (2012). *The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education*. Hoboken: John Wiley & Sons.

7. Popkin, H. (2010, June 1). *FarmVille invades the real world*. Retrieved from https://www.nbcnews.com/id/wbna37451547

8. Papadakis, S., & Kalogiannakis, M. (2018). *Using Gamification for Supporting an Introductory Programming Course. The Case of Classcraft in a Secondary Education Classroom*. Retrieved from https://www.researchgate.net/publication/322021498_Using_Gamification_for_Supporting_an_Introductory_Programming_Course_The_Case_of_ClassCraft_in_a_Secondary_Education_Classroom

9. Creswell, J. W. (2003). *Research Design. Qualitative, Quantitative, and Mixed Methods Approaches*. London: Sage Publication.

10. Neuman, W. L. (2011). *Social Research Methods. Qualitative and Quantitative Approaches*. Boston: Pearson.

11. Berg, B. L., & Howard, L. (2009). *Qualitative Research Methods for the Social Sciences*. Boston: Pearson.

12. Kaptan, K., & Timurlenk, O. (2012). Challenges for Science Education. *Procedia - Social and Behavioral Sciences, 51*, 763–771. doi: 10.1016/j.sbspro.2012.08.237

13. Gardner, P. L. (1975). Attitudes to science. *Studies in Science Education, 2*, 1–41.

14. Klopfer, L. E. (1971). Evaluation of learning in science. In B. S. Bloom, *The Handbook of Formative and Summative Evaluation of Student Learning* (pp. 559–641). New York: McGraw Hill.

15. Fraser, J. B. (1978). Development of a test of science-related attitudes. *Science Education, 62*(4), 509–515.

16. Yager, R. E. (1996). *Science/technology/society as reform in science education*. Albany: State University of New York Press.

17. Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching, 25*(8), 689–703. doi: 10.1002/tea.3660250807

18. Jarvis, T., & Pell, A. (2004). Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre. *Journal of Research in Science Teaching, 42*(1), 53–83. doi: 10.1002/tea.20045

19. Broggy, J., O'reilly, J., & Erduran, S. (2017). Interdisciplinarity and Science Education. *Science Education*, 81–90. doi: 10.1007/978-94-6300-749-8_6

20. Kirby, P., & Cullinane, C. (2017). Science shortfall. *The Sutton Trust: Research Brief, 17*, 1–8.

21. De Broucker, P., Bordt, M., Read, C., Harris, S., & Zhang, Y. (2001). Determinants of science and technology skills: Overview of the study. *Education Quarterly Review, 8*(1), 8–16.

22. Dekkers, J., & De Laeter, J. (2001). Enrolment trends in school science education in Australia. *International Journal of Science Education, 23*(5), 487–500. doi: 10.1080/09500690118451

23. Pell, T., & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education, 23*(8), 847–862. doi: 10.1080/09500690010016111

24. Toma, R. B., Greca, I. M., & Orozco Gómez, M. L. (2019). Attitudes towards science and views of nature of science among elementary school students in terms of gender, cultural background and grade level variables. *Research in Science & Technological Education, 37*(4), 492–515. doi: 10.1080/02635143.2018.1561433

25. Gundogdu, T. (2014). *The analysis of the relationship between 8th-grade students' success and conceptual understanding of astronomy and their attitudes towards science courses*. Istanbul: Marmara University Institute of Educational Sciences.

26. Watson, W. R., Mong, C. J., & Harris, C. A. (2011). A case study of the in-class use of a video game for teaching high school history. *Computers & Education, 56*(2), 466–474. doi: 10.1016/j.compedu.2010.09.007

27. Amiruddin, A., Briliyant, O. C., & Trianto, N. (2020). Systematic Literature Review of Game-Based Learning: Objectives, Methods, Applications, Measurement Parameters, and Types of Games. *2020 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)*. doi: 10.1109/icimcis51567.2020.9354296

28. Bubar, E., Agolini, S., Jaber, D., & Wright, A. (2021). Three Methods for Adapting Physical Games to Virtual Formats in STEM Courses – Easy (Google Suite), Medium (Web GL Games in Unity) and Hard (Virtual Reality). *Communications in Computer and Information Science*, 141–147. doi: 10.1007/978-3-030-78645-8_18

29. Alexandropoulou, A., & Tsezou, A. –Spyridoula. (2023). *Teaching science, sustainability and technology through gamification: The approach of escape rooms*. doi: 10.5194/egusphere-egu23-7397

30. Klock, A. C. T., Ogawa, A. N., Gasparini, I., & Pimenta, M. S. (2018). Does gamification matter? *Proceedings of the 33rd Annual ACM Symposium on Applied Computing*. doi: 10.1145/3167132.3167347

31. Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371–380. doi: 10.1016/j.chb.2016.12.033

32. Kam, A. H., & Umar, I. N. (2018). Fostering Authentic Learning Motivations through Gamification: A Self-Determination Theory (SDT) Approach. *Journal of Engineering Science and Technology*, *13,* 1–9.

33. Lee, J. J., & Hammer, J. (2011). *Gamification in Education: What, How, Why Bother?* Retrieved from https://www.researchgate.net/publication/258697764_Gamification_in_Education_What_How_Why_Bother

34. Lyons, T. (2006). Different Countries, Same Science Classes: Students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591–613. doi: 10.1080/09500690500339621

35. Oh, P. S., & Yager, R. E. (2004). Development of Constructivist Science Classrooms and Changes in Student Attitudes toward Science Learning. Science Education International, 15(2), 105–113.

36. Koster, R. (2004). *A theory of fun*. New York: O'Reilly Media.

37. Antonenko, P. D., & Thompson, A. D. (2009). Preservice teachers' perspectives on the definition and assessment of creativity and the role of web design in developing creative potential. *Education and Information Technologies, 16*(2), 203–224. doi: 10.1007/s10639-009-9112-1

40. Barak, M., Ashkar, T., & Dori, Y. J. (2011). Learning science via animated movies: Its effect on students' thinking and motivation. *Computers & Education, 56*(3), 839–846. doi: 10.1016/j.compedu.2010.10.025

41. Borges, C. N., & Fleith, D. de S. (2018). Uso da Tecnologia na Prática Pedagógica: Influência na Criatividade e Motivação de Alunos do Ensino Fundamental. *Psicologia: Teoria e Pesquisa, 34*(0). doi: 10.1590/0102.3772e3435

40. Sauerland, W., Broer, J., & Breiter, A. (2015). *The motivational impact of gamification for mobile learning of kanji, Proceedings of E- media*. Retrieved from https://www.ifib.de/fileadmin/ifib/publikationsdateien/Sauerland_etal-2015.pdf

41. McGonigal, J. (2011). *Reality Is Broken: Why Games Make Us Better and How They Can Change the World*. New York: Penguin.

42. Pramana, D. (2016). Designing knowledge sharing applications with the concept of gamification. *Journal of Systems and Informatics, 10*(1).

43. Buckley, P., & Doyle, E. (2014). Gamification and student motivation. *Interactive Learning Environments, 24*(6), 1162–1175. doi: 10.1080/10494820.2014.964263

44. Ming, T. S., Ling, T. S., & Jaafar, N. M. (2011). Attitudes and motivation of Malaysian secondary students towards learning English as a second language: A case study. *3L: Language, Linguistics, Literature, 17*(1), 40–54.

45. Omar, S. F., Nawi, H. S. A., Tengku Shahdan, T. S., Mee Mee, R. W., Pek, L. S., & Che Yob, F. S. (2020). Interactive language learning activities for learners' communicative ability. *International Journal of Evaluation and Research in Education (IJERE), 9*(4), 1010. doi: 10.11591/ijere.v9i4.20605

46. Seong Pek, L., & Mee Mee, R. W. (2016). Selfie: Engaging Life Experiences into Writing. *Malaysian Journal of Distance Education, 17*(2), 51–66. doi: 10.21315/mjde2015.17.2.4

47. Fleith, D. S. (2017). Effects of Creativity Training Programs on Individual Characteristics. *The Cambridge Handbook of Creativity and Personality Research*, 391–404. doi: 10.1017/9781316228036.020

48. Hennessey, B. A. (2010). The Creativity-Motivation Connection. *The Cambridge Handbook of Creativity*, 342–365. doi: 10.1017/cbo9780511763205.022

49. Sternberg, R. J. (2006). The nature of creativity. *Creativity Research Journal, 18*(1), 87–98.

50. Ricoy, M.-C., & Sánchez-Martínez, C. (2022). Raising Ecological Awareness and Digital Literacy in Primary School Children through Gamification. *International Journal of Environmental Research and Public Health, 19*(3), 1149. doi: 10.3390/ijerph19031149

51. Salen, K. (2008). *The Ecology of Games: Connecting Youth, Games, and Learning*. Cambridge: The MIT Press.

52. Squire, K. (2006). From Content to Context: Videogames as Designed Experience. *Educational Researcher, 35*(8), 19–29. doi: 10.3102/0013189x035008019

53. Guo, S., Liu, C., & Liu, E. (2022). An exploration of multilevel effects of student- and school-factors on elementary students' attitudes towards science. *International Journal of Science Education, 44*(15), 2330–2352. doi: 10.1080/09500693.2022.2120373

54. Schibeci, R. A. (1984). Attitudes to science: an update. *Studies in Science Education, 11*(1), 26–59. doi: 10.1080/03057268408559913

55. Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*(4), 387–398. doi: 10.1002/tea.3660320407

56. Jerrim, J., & Schoon, I. (2014). Do teenagers want to become scientists? *Gender Differences in Aspirations and Attainment*, 203–223. doi: 10.1017/cbo9781139128933.014

57, Wan, Z. H., & Lee, J. C. K. (2017). Hong Kong secondary school students' attitudes towards science: a study of structural models and gender differences. *International Journal of Science Education, 39*(5), 507–527. doi: 10.1080/09500693.2017.1292015

58. Arısoy, N. (2007). *Examining 8th-grade students' perception of learning environment of science classrooms in relation to motivational beliefs and attitudes*. Retrieved from https://open.metu.edu.tr/handle/11511/16693

59. Lawrenz, F. P. (1976). *Student perception of the classroom learning environment in biology, chemistry and physics courses*. Retrieved from https://files.eric.ed.gov/fulltext/ED161681.pdf

60. Simpson, R. D., & Steve Oliver, J. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74*(1), 1–18. doi: 10.1002/sce.3730740102

61. Zin, S. (1999). *Chemistry learning environment in Brunei Darusssalam's secondary schools*. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000120273

62. Aldolphe, F. (2003). *A cross-national study of learning environment and attitudes among junior secondary science students in Australia and Indonesia*. Retrieved from https://espace.curtin.edu.au/handle/20.500.11937/547

63. Zaitoun, A. (2008). *Methods of Teaching Science* (2nd ed.). Amman: Al Shorouk for Publishing and Distribution.

64. Chan, K. Y. G., Tan, S. L., Hew, K. F. T., Koh, B. G., Lim, L. S., & Yong, J. C. (2017). Knowledge for games, games for knowledge: designing a digital roll-and-move board game for a law of torts class. *Research and Practice in Technology Enhanced Learning, 12*(1). doi: 10.1186/s41039-016-0045-1

65. Kim, B., Park, H., & Baek, Y. (2009). Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learning. *Computers & Education, 52*(4), 800–810. doi: 10.1016/j.compedu.2008.12.004

66. Loganathan, P., Talib, C., Thoe, N., Aliyu, F., & Zawadski, R. (2019). Implementing Technology Infused Gamification in Science Classroom: A Systematic Review and Suggestions for Future Research. *Learning Science and Mathematics*, *14*, 60–73.