European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available online at: www.oapub.org/edu

DOI: 10.46827/ejes.v10i10.4993 Volume 10 | Issue 10 | 2023

MOTIVATING STUDENTS IN THE BIOLOGY CLASSROOM VIA GAMES

Martha Georgiou[i],
Marina Pandi
Department of Biology,
National and Kapodistrian University of Athens,
Greece

Abstract:
In recent decades, the increased use of digital games by students at all education levels has attracted the attention of many researchers interested in the effect games used in the classroom have on learning. Despite the strong interest internationally in the use of educational games in the teaching of Biology, in Greece the degree of corresponding research is limited. The purpose of our research is to examine the effect that games have on Greek high school students' acquisition and retention of knowledge relating to genetics concepts. The sample consisted of 32 K-9 students, who were divided into two groups. In the first group, the chosen teaching approach was based on the traditional teaching method, while in the second group, it was based on the use of an educational genetics card game. All students completed the same assessment test both before and immediately after the teaching interventions. Based on the results, it was found that both approaches yielded statistically similar learning outcomes, with students in the group taught by the game-teaching approach performing better on average than those in the control group.

Keywords: motivating students, genetics, educational game, traditional teaching, learning outcomes, assessing knowledge retention

1. Introduction

The increasing use of games by students outside school has attracted the interest of researchers, educators, and curriculum designers. For this reason, there is a wealth of research on the use and effectiveness of games in the educational process (Gourgiotou, 2009; Hwang et al., 2013; Li and Tsai, 2013; Sung and Hwang, 2013; Sadler et al., 2015; Papazoglou, 2016; Papadakis, 2018; van Gaalen et al., 2021). While the above research shows that games used as teaching aids yield positive results for both teachers and students at all levels of education, the efficacy of using a game in one area of learning

[i] Correspondence: email martgeor@biol.uoa.gr

when applied to a specific group of students does not mean that it will be the same for all games, in all areas and with all students (Hays, 2005). For instance, although card, board, or digital games have similar effectiveness, often a digital game may require a longer period of engagement from players before they become familiar with the game environment, and then benefit from learning (Annetta et al., 2009; Onisiforou, 2014).

Perhaps the secret of success relating to the use of games lies in the careful design or selection of the appropriate game which fits both the learning objectives themselves (Rastegarpour and Marashi, 2012) and the standards against which they are evaluated; in other words, if the game achieves the teaching goals of the subject it aims to teach, it can also serve as an evaluation tool to highlight the benefits that students gain from it (Hogle, 1996).

2. Literature review

2.1 Educational games

A. What Educational Games are, and how they are used in the educational process

A very popular term referring to all kinds of learning and education based mainly today on digital games (e.g., business, military, medical, marketing, etc.) is the term "*serious games*" (Cheng, 2013), which we will herein expand by replacing it with the enhanced term "*educational games*". At the time, 1970, that Abt (1970) introduced the former term (and Ben Sawyer popularized it in 2002), it referred mainly to board games and card games which had no entertainment purpose and solely promoted a serious purpose (Cheng et al., 2015; Tentolouri, 2015). These are games that have a clear and carefully studied educational goal, and are not primarily intended for fun (Tentolouri, 2015).

According to Hays (2005), there are specific cases and reasons that educational games can be employed in teaching. Thus, games could be used to assess the students' cognitive level, when they are required to attain a specific educational level and measure students' performance based on specifically designed evaluation criteria. They also could provide course content to students, help them become familiar with special knowledge and skills areas, and at the same time help them change their own behaviors and attitudes. Moreover, educational games could act as an engaging lesson pre-organizer that can be employed before other forms of teaching, replacing them with regard to the presentation of pertinent information or the development of students' skills. Finally, they could have an important role in enhancing students' retention and assimilation of knowledge and related skills (Hays, 2005).

B. The importance of using games in Biology teaching

Biology studies living organisms that have structures and functions which evolve and have the ability to respond and adapt to the changes and demands of the natural environment. The interactions of living organisms constitute a complex network that is difficult to manage, both within the science of Biology itself and in the process of teaching its concepts. In a Biology class, this large mass of information often discourages students who are taught using the traditional approach of the oral presentation by the teacher, followed by students working alone to complete an activity or worksheet. Since game-based learning relies heavily on collaboration between students, it is an approach related to the theory of constructivism: Students learn not only by themselves, but also from fellow students (Athanasiou and Papadopoulou, 2015). Thus, to enhance the learning of a variety of biological concepts, some carefully selected educational games could be introduced as soon as students are taught the basic components of a particular course (Spiegel et al., 2018).

Following are descriptions of several attempts by teachers and researchers to introduce educational games into Biology lessons. Based on these studies, it seems that educational games do in fact promote students' knowledge retention and motivation of biological topics:

Vaccines, vaccination, immune system, and lymphocytes were the concepts around which a corresponding educational game was designed for K-10 students, giving encouraging results when implemented to 22 students, in terms of developing their reasoning skills on similar issues (Maniatakou et al., 2020). Cardoso et al. (2008) developed an interdisciplinary board game involving the human immune system response against a bacterial infection for teaching molecular biology at a high school. Their results were positive, as teachers and students found this game an easy and interesting tool for teaching the aforementioned topics, and at the same time, the correct answers in the students' post-test increased by 5-30% (compared to the previous pre-test). Gutierrez (2014) describing the learning outcomes of an educational card game designed on biological concepts for the biology classes at Bulacan State, points out that statistically significant differences were found in favour of the card game compared to the traditional teaching methods. Additionally, students who played evaluated the card game as very satisfactory using five criteria: goals, design, organization, playability, and usefulness.

As the above examples show, educational games, in general, are a useful teaching tool at various educational levels, because they often motivate students (Cheng et al., 2015), facilitate the acquisition of knowledge and skills, increase the engagement in the learning process (Annetta et al., 2009), improve performance, contribute to a better understanding of abstract concepts and principles of science/biology (Cheng et al., 2015; van Gaalen et al., 2021), evoke pleasure and joy, and can improve retention of information in the long term (van Gaalen et al., 2021).

2.2 Purpose of the research and research questions

The present research paper aims to examine the acquisition and understanding of certain concepts of Genetics by third-year Greek high school students (K-9) through two different teaching approaches: one approach is based on the traditional method in which the teacher presents material orally, after which the students work individually to complete a worksheet, while the other is based on the collaborative method, which utilizes an educational game with cards built around hybridization.

The educational goals that students were expected to achieve in both cases included:

1) locating the alleles of a gene in a chromosome representation

2) distinguishing the dominant from the recessive alleles of a gene and representing them in uppercase and lowercase alphabet letters, respectively
3) distinguishing the genotype from the phenotype
4) identifying a heterozygous and homozygous individual (relating to a specific trait) and forming their genotypes.

More specifically, the research questions that arose are:

a) Does the use of an educational card game yield better learning outcomes than the traditional teaching method?
b) Does the use of an educational card game enhance the retention of the corresponding concepts?
c) Does the use of an educational card game enhance students' interest in Biology?

3. Methodology

In our research, we examined whether there is a relationship between the independent variable (teaching approach: traditional vs educational game) and the dependent variable (student performance) (Elliot et al., 2002). In order to ensure the objectivity of the research, all the factors of the research, i.e., the educational objectives of the course, the assessment test, the duration of the educational interventions, and the teacher who performed the interventions, were kept constant; only the educational approach was differentiated.

3.1 Research sample

A convenience sample of high school students was used. The sample was comprised of 32 K-9 students (15 years old) from two classes of a public high school in Athens. They were divided into two groups (with equal sex distribution) of 16 students: the first 16 students formed the experimental group, which was taught via the Genetics game ("the game group" / gg), while the rest formed the control group, which were taught using the traditional approach ("the traditional group" / tg).

3.2 Research tool for data collection

3.2.1 The Knowledge Test

The data collection tool was an assessment test consisting of 22 multiple choice questions, which we structured according to Bloom's Taxonomy educational goals (Bloom, 1956) that we had originally set and described in the section above, and addressed the topics that the students were to be taught. The test was initially administered to 5 people (1 biology University Professor, 1 secondary biology teacher, 2 biology education researchers, 1 science education researcher) to ensure the validity (face validity) of the instrument. After their suggestions, the test was given its final form.

For each question, there was one correct answer out of four possible answers. All students had to state how confident they were about their answer by choosing one of three "degree of confidence" options (Π = very sure, M = moderately sure, or K = not at all sure) to identify any randomly chosen correct answers. An indicative sample of the Knowledge Test is presented in Figure 1.

Knowledge Test		
Date: …………………… Student: ……………………………		
1. How confident are you about your answers?		
Very sure (Π)	Moderately sure (M)	Not at all sure (K)

1. What is the term that describes the process of parents passing on characteristics to their offspring?			
A. Genes	B. Heredity	C. Chromosomes	D. DNA
2. Which contains the complete “package” of information about the characteristics we inherit from our parents?			
A. Chromosomes	B. Genes	C. RNA	D. Alleles
3. The gene is part of the chromosome that…			
A. codes for a specific characteristic	B. determines the sequence of amino acids in a protein	C. is responsible for causing diseases transmitted from parents to children	D. All three
4. The organisms that carry two sets of chromosomes, one from the father and one from the mother, are:			
A. haploids	B. prokaryotes	C. diploids	D. monocytes

Figure 1: Indicative Sample of the Knowledge Test

The test was initially conducted prior to the intervention in order to assess the knowledge of students in both the gg and tg groups (i.e., the pre-test), and was also conducted immediately after the completion of the teaching intervention (i.e., the post-test). The answers that were considered as correct were the ones where the students gave scientifically sound answers, while at the same time, they were adequately certain of their answers. To check the degree of knowledge retention, we conducted the same test one month later.

3.2.2 Instructional Materials Motivation Survey (IMMS) questionnaire

IMMS is a reliable and valid assessment tool relating to the use of an educational game in the classroom which measures the degree of students' motivation in relation to the educational material of a particular course, and contains 36 Likert scale questions (Keller, 2009; Brits and van Oordt, 2018). As described by Brits and van Oordt (2018) and Keller (2009), it was designed based on the theoretical model ARCS (attention = attention, relevance = correlation, confidence = confidence, satisfaction = satisfaction) by J. Keller, and was based on a synthesis of psychological theories about human motivation based on empirical data.

The IMMS questionnaire "*refers to the students' motivation for learning, and indicates their willingness, desire, need or even compulsion to participate in the game and successfully complete the whole educational process*" (Brits and van Oordt, 2018).

The 36 questions it contains consist of:

- 12 questions that evaluate the content of the lesson and investigate whether the organization of the lesson both attracts and retains the attention of students, and ensures the avoidance of boredom (i.e., attention questions)
- 9 questions assessing whether the new knowledge is related to students' previous knowledge and experiences as well as their abilities and needs, and whether students will apply this knowledge in the future (i.e., correlation questions)
- 9 questions assessing the extent to which the learner has encountered difficulties in understanding the new knowledge, and to what extent they consider that the way the lesson is presented (through the game) ensures effective learning and success (i.e., confidence questions).
- 6 questions focusing on the positive feelings that the student had during the lesson and the satisfaction they felt after having understood the lesson and acquired a complete perception of it (i.e., satisfaction questions) (Keller, 1987; Brits and van Oordt, 2018).

3.3 Conducting the research

The survey was conducted during the months of April-June of the school year 2022. The application of the research required five teaching hours for each group, regardless of the teaching method that was followed. The content of each intervention teaching hour is shown in Table 1. Finally, to evaluate the retention of the learned knowledge, we conducted the same Knowledge Test at the end of June.

3.4 The intervention

In the first lesson, students from both groups were asked to complete the assessment test (the pre-test) so that the researchers could identify students' prior knowledge. In the second lesson, both groups attended the same PowerPoint presentation dealing with concepts of Genetics (such as heredity, chromosomes, genes, homologous chromosomes, alleles, dominant and recessive genes, phenotype, genotype, gametes, fertilization, etc.). In the third and fourth teaching sessions, the games group played the Genetics game, while the traditional group completed the worksheet which generally was used in the traditional teaching approach (notation of genetic concepts and simple exercises on them). In the fifth teaching session, both groups completed the same assessment test (the post-test) that they had completed during the first teaching hour (Table 1). Additionally, the students of the game group filled out the IMMS questionnaire.

A. Game teaching approach: "Small creature, what do you look like?"

The experimental group (gg) approached the concepts of Genetics through the use of the educational card game *"Small creature, what do you look like?"*, which had been created by the researchers. The students played the Genetics card game in groups of four. Within each four-member team, two opposing pairs were formed, playing the game in turns, and at any single time there were two players and two observers/rule keepers who kept track of the rules and the score.

In more detail, each team tried to determine the phenotype and/or genotype of the "small creatures" illustrated on each card randomly selected, while the opposing team had to check the result in order to credit the corresponding points. In this way, students had to interpret genotypes and/ or phenotypes. After all the cards had been drawn, the team with the most points won.

B. Traditional teaching approach

The control group followed the traditional teaching approach. Thus, during the third and fourth teaching hours, the students of the control group (tg) were evaluated on their knowledge of the same concepts as the experimental group, but worked individually to complete a printed worksheet designed to evaluate their understanding of the concepts presented. The following is an extract from the worksheet (Figure 2).

1. In humans, hair color is controlled by a dominant allele (T) which produces black hair, and a recessive allele (t) that produces red hair.
Genotypes for black hair …………… or ………….
Genotype for red hair …………..

2. Eye color is controlled by a dominant allele (A) that forms brown eyes, and a recessive allele (a) that forms blue eyes.
Genotype for brown eyes …………… .or …………
Genotype for blue eyes ……… ..

3. The picture below shows an egg and a sperm.
a. If fertilization takes place between them, what will be the genotype and phenotype of the offspring that will emerge? What will the sex of the offspring be? (T, t = alleles for hair color, and A, a alleles for eye color)
genotype ………………………. phenotype ………………… sex …………………

Figure 2: Extract from the tg students' worksheet

4. Results

In order to extract the results, the students' answers were processed with the help of the SPSS statistical package. Descriptive statistics were performed to answer the research questions and, although the number of students in the sample was relatively small, the statistical test of means for two independent groups (independent samples t-test) was used to make an initial comparison and a first imprint of the trends.

4.1 Comparison of post-intervention tests between the game group and the traditional group

After the intervention, a statistical test (independent samples t-test) of the means of the answers to the evaluation tests of the two groups was performed to compare their performance in terms of the effectiveness of the teaching method. Tables 2 and 3 present the data analysis from these post-tests. The results did not show a statistically significant difference between the performance of the students in the game group and those in the traditional group after the intervention. However, the game group tended to outperform the traditional group, on average.

4.2 Measurement of post-intervention retention of knowledge

In order to investigate whether the knowledge gained after the intervention was better retained by the game group than the traditional group, students were asked to once again complete the same Knowledge Test they had taken before and after the intervention. We performed the independent samples t-test on the students' responses, and did not observe a statistically significant difference (sig = 0.319 and t = 0.978) in terms of the retention of knowledge taught, with the game group having slightly better retention than the traditional group (Table 4).

The purpose was to determine to what degree the students were motivated and how they felt during and after the game, both overall and in relation to the four subcategories of the IMMS questionnaire (i.e., Attention, Correlation, Confidence, and Satisfaction). For our purposes, a score of 3-4 is considered high as it refers to the answers "3 = I quite agree" and "4 = I totally agree" that the levels measure.

Along with the overall motivation, based on the average scores of the individual sub-categories, it is evident that the game attracted more student attention and interest and created a feeling of satisfaction and pleasure both during and after its application. In addition, the correlation with previous knowledge, experiences, and needs of the students (2nd subcategory) had a slightly lower score than the other subcategories, while the belief that the material could be learned quite easily was at a high level, thus demonstrating that the game playing creates strong learning motivation.

Table 5 below shows the average scores and the standard deviation of each subcategory of the IMMS questionnaire.

5. Discussion and Conclusion

This research is part of a broader research endeavour. Thus, the effectiveness of each of the teaching approaches was tested separately, and a statistically significant difference emerged before and after the interventions in terms of learning outcomes. In other words, it seemed that both methods could achieve the cognitive goals that were originally set. At this point, however, we wanted to learn if there were comparative differences regarding the degree of success of the learning outcomes based on the educational approach. The findings of the present study showed that immediately after the intervention, students who played the game of Genetics had statistically the same performance as their counterparts in the traditional group, although the former tended to exhibit better average learning results.

In addition, we had the same findings regarding the retention of knowledge after the two educational interventions: We did not find a statistically significant difference between the two groups, but in the case of students who had approached the concepts of Genetics through the game, the retention trend was found to be an increasing one.

The teaching content and activities that emerged during the playing of the game, the interpersonal processes and relationships that developed between the students during the game, as well as the pleasant atmosphere inside the classroom, may all have influenced the students, leading us to record a positive trend in favor of this kind of teaching approach. On the other hand, the manner in which students learn, i.e., some students may find it easier to learn through games while others may not, or some students may prefer to work in groups while others prefer to work individually (Hogle, 1996), as well as the fact that students, at least in Greece, are more accustomed to the traditional way of teaching which does not include any games, may have led to non-statistically significant differences in results between the two groups. Needless to say, we should take into account the fact that our sample was small, which forced us to mainly accept the findings of the descriptive statistics analysis; this has brought to our attention the need to expand our sample in the future in order to reach more concise conclusions from the statistical significance methods.

Regarding the IMMS test, the research has revealed that the students who were taught through the game method were greatly motivated: The game attracted their attention, created feelings of self-confidence and trust in the knowledge they acquired during the intervention, and at the same time gave rise to positive feelings and satisfaction because they had been able to complete the activity successfully. In general, it seems that alternative forms of education have positive outcomes for students (Georgiou and Mavrikaki, 2013; Georgiou et al., 2020a; 2020b; 2020c; Paxinou et al., 2022; Gata et al., 2023) and it is important to explore and combine them with forms of formal education in order to ensure both better learning outcomes and feelings of pleasure from the learning process (Georgiou et al., 2022; Sá-Pinto et al., 2022; de Lima et al., 2023).

In conclusion, in accordance with Telner et al. (2010) whereby *"Involvement in this form of learning makes games a very promising form of education in the teaching of Biology"*, it would be worthwhile to invest time and effort in them in the future so as to further investigate and evaluate the learning outcomes that they yield.

Conflict of Interest Statement
The authors declare no conflicts of interest.

About the Authors

Martha Georgiou is a full-time instructor and researcher at the Department of Biology of the National and Kapodistrian University of Athens, specializing in Biology Teaching (BSc in Biology, MEd and PhD in Science Education). She teaches "Science/Biology Education" at undergraduate and postgraduate levels in the same department as well as in other departments in Greece and abroad (University of Sorbonne). She has authored articles, and chapters in books but has also participated in national curriculum writing groups.

Marina Pandi is a secondary Biology teacher with postgraduate studies in Biology Education. She teaches in an experimental school from K-7 to K-12.

References

Abt, C. (1970). *Serious games* New York: The Viking Press

Annetta, L. A., Minogue, J., Holmes, S. Y., and Cheng, M. T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers and Education*, 53(1), 74-85. https://doi.org/10.1016/j.compedu.2008.12.020

Athanasiou, K., and Papadopoulou, P. (2015). Evolution Theory Teaching and Learning: What Conclusions Can We Get From Comparisons of Teachers' and Students' Conceptual Ecologies in Greece and Turkey?. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(4), 841-853. https://doi.org/10.12973/eurasia.2015.1443a

Bloom, B. S. (1956). *Taxonomy of Educational Objectives, Handbook 1: Cognitive Domain*. New York: Longman.

Brits, L., and van Oordt, T. (2018). The Perceived Motivational Impact of Voice-over-PowerPoint™ on Part-time Adult Learners in a Distance Learning Environment. *Alternation Journal*, (23), 134-168.

Cardoso, F. S., Dumpel, R., da Silva, L. B. G., Rodrigues, C. R., Santos, D. O., Cabral, L. M., and Castro, H. C. (2008). Just working with the cellular machine: a high school game for teaching molecular biology. *Biochemistry and Molecular Biology Education*, *36*(2), 120-124. https://doi.org/10.1002/bmb.20164

Cheng, M. T., Chen, J. H., Chu, S. J., and Chen, S. Y. (2015). The use of serious games in science education: A review of selected empirical research from 2002 to 2013. *Journal of Computers in Education*, *2*(3), 353-375. https://doi.org/10.1007/s40692-015-0039-9

de Lima, J., Adnađević, T., Barstad, J., Georgiou, M., Holm, S., Kenig, B., ... and Milosevic, T. (2023). Developing non-formal learning activities focused on increasing evolutionary knowledge and scientific literacy. https://doi.org/10.5281/zenodo.7711038

Elliot, S. N., Kratochwill, T. R., Cook, J. L., Travers, J. F. (2002). *Educational psychology: effective teaching, effective learning.* Bosten: McGraw-Hill.

Gourgiotou, E. (2009). Play and learning: Inseparable concepts in preschool practice, *Deltio*, 42, 3-7. (in Greek)

Gata, D., Valakos, E., and Georgiou, M. (2023). Engaging and assessing students via a museum educational program. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(10), em2334. https://doi.org/10.29333/ejmste/13574

Georgiou M. and Mavrikaki E. (2013). Greek students' ability in argumentation and informal reasoning about socio-scientific issues related to biotechnology. In C. P. Constantinou, N. Papadouris, and A. Hadjigeorgiou (Eds.), *Proceedings of the 10th Conference of the European Science Education Research Association* (pp. 1158-1166).

Georgiou, M., Mavrikaki, E., Halkia, K., and Papassideri, I. (2020a). Investigating the impact of the duration of engagement in socioscientific issues in developing Greek students' argumentation and informal reasoning skills. *American Journal of Educational Research*, *8*(1), 16-23. https://doi.org/10.12691/education-8-1-3

Georgiou, M., Mavrikaki, E., & Constantinou, C. P. (2020b) Is teaching biology through socio-scientific issues enough for the development of argumentation skills? In B. Puig, P. B. Anaya, M. J. G. Quilez, & M. Grace (Eds.), Biology education research. Contemporary topics and directions (pp. 177- 186). Servicio de Publicaciones [Publications Service], Universidad de Zaragoza. https://doi.org/10.26754/uz.978-84-16723-97-3

Georgiou, M., Ziogka, K., and Galani, L. (2020c). Are Pre-Service Teachers Ready to Write Stories in the Sciences?. *Interdisciplinary Journal of Environmental and Science Education*, *16*(4), e2220. https://doi.org/10.29333/ijese/8421

Georgiou, M., Fonseca, M.J., Fortin, C., Turpin, S. and Roux-Goupille, C. (2022). SSI approach out of schools - How can these approaches be used in science museums and other non formal education contexts? In Xa-Pinto X, Bennierman, A., Børsen, T.H., Georgiou, M., Jeffries, A., Pessoa, P., Soussa, B. and Zeidler, D. (Eds) *Learning evolution through socioscientific issues.* Aveiro, Portugal: UA Editora. https://doi.org/10.48528/4sjc-kj23

Gutierrez, A. F. (2014). Development and effectiveness of an educational card game as supplementary material in understanding selected topics in biology. *CBE—Life Sciences Education*, *13*(1), 76-82. https://doi.org/10.1187/cbe.13-05-0093

Hays, R. T. (2005). *The effectiveness of instructional games: A literature review and discussion* (No. NAWCTSD-TR-2005-004). Naval Air Warfare Center Training Systems, Div Orlando FL

Hogle, J. G. (1996). *Considering games as cognitive tools: In search of effective "edutainment"*. ERIC Clearinghouse

Hwang, G. J., Sung, H. Y., Hung, C. M., Yang, L. H., and Huang, I. (2013). A knowledge engineering approach to developing educational computer games for improving students' differentiating knowledge. *British journal of educational technology*, *44*(2), 183-196. https://doi.org/10.1111/j.1467-8535.2012.01285.x

Keller, J. M. (1987). Strategies for stimulating the motivation to learn. *Performance and instruction*, 26(8), 1-7.

Keller, J. M. (2009). *Motivational design for learning and performance: The ARCS model approach*. Springer Science and Business Media

Li, M. C., and Tsai, C. C. (2013). Game-based learning in science education: A review of relevant research. *Journal of Science Education and Technology*, *22*(6), 877-898. https://doi.org/10.1007/s10956-013-9436-x

Maniatakou, A., Papassideri, I., and Georgiou, M. (2020). Role-play activities as a framework for developing argumentation skills on biological issues in secondary education. *American Journal of Educational Research*, *8*(1), 7-15. 15. https://doi.org/10.12691/education-8-1-2

Onisiforou, M. (2014). Digital games in education: motivation and learning. Retrieved 3/5/23 https://ktisis.cut.ac.cy/bitstream/20.500.14279/458/2/Miranda_Onisiforou.pdf

(Bachelor's thesis, Department of Communication and Internet Studies, School of Communication and Media Studies, Cyprus University of Technology, in Greek)

Papadakis, S. (2018). The use of computer games in classroom environment. *International Journal of Teaching and Case Studies*, *9*(1), 1-25. https://doi.org/10.1504/IJTCS.2018.090191

Papazoglou, M. (2016). The use of board games in the teaching of physics concepts in primary school: exploring the effects on achievement and motivation. Retrieved 3/5/23 https://ir.lib.uth.gr/xmlui/bitstream/handle/11615/45862/15108.pdf?sequence=1andisAllowed=y (Master's thesis, Department of Primary Education, University of Thessaly, in Greek)

Paxinou, E., Georgiou, M., Kakkos, V., Kalles, D., and Galani, L. (2022). Achieving educational goals in microscopy education by adopting virtual reality labs on top of face-to-face tutorials. *Research in Science and Technological Education*, *40*(3), 320-339. https://doi.org/10.1080/02635143.2020.1790513

Rastegarpour, H., and Marashi, P. (2012). The effect of card games and computer games on learning of chemistry concepts. *Procedia-Social and Behavioral Sciences*, 31, 597-601. https://doi.org/10.1016/j.sbspro.2011.12.111

Sadler, T. D., Romine, W. L., Menon, D., Ferdig, R. E., and Annetta, L. (2015). Learning biology through innovative curricula: A comparison of game-and nongame-based approaches. *Science Education*, *99*(4), 696-720. https://doi.org/10.1002/sce.21171

Sá-Pinto, X., Bennierman, A., Børsen, T.H., Georgiou, M., Jeffries, A., Pessoa, P., Soussa, B. and Zeidler, D. (2022) *Learning Evolution through socioscientific issues.* Aveiro, Portugal: UA Editora. https://doi.org/10.48528/4sjc-kj23

Spiegel, C. N., Alves, G. G., Cardona, T. D. S., Melim, L. M., Luz, M. R., Araújo-Jorge, T. C., and Henriques-Pons, A. (2008). Discovering the cell: an educational game about cell and molecular biology. *Journal of Biological Education*, 43(1), 27-36. https://doi.org/10.1080/00219266.2008.9656146

Sung, H. Y., and Hwang, G. J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers and education*, 63, 43-51. https://doi.org/10.1016/j.compedu.2012.11.019

Telner, D., Bujas-Bobanovic, M., Chan, D., Chester, B., Marlow, B., Meuser, J., and Harvey, B. (2010). Game-based versus traditional case-based learning: comparing effectiveness in stroke continuing medical education. *Canadian Family Physician*, 56(9), e345-e351

Tentolouri, A. M. (2015). Characterization of Serious Games with educational metadata. (Master's thesis, University of Piraeus, in Greek)

van Gaalen, A. E., Brouwer, J., Schönrock-Adema, J., Bouwkamp-Timmer, T., Jaarsma, A. D. C., and Georgiadis, J. R. (2021). Gamification of health professions education: a systematic review. *Advances in Health Sciences Education*, *26*(2), 683-711. https://doi.org/10.1007/s10459-020-10000-3

Appendix

Table 1: Content of intervention teaching hours

Students' group	1st teaching hour	2nd teaching hour	3rd teaching hour	4th teaching hour	5th teaching hour
Traditional group (tg)	Pre-test	PowerPoint presentation	Worksheet	Worksheet	Post-test
Game group (gg)	Pre-test	PowerPoint presentation	Genetics game	Genetics game	Post-test + IMMS questionnaire

Table 2: Group Statistics

	Students' group	N	Mean	Std. Deviation	Std. Error Mean
Post-test	Traditional group - tg	16	9.75	5.675	1.419
	Game group - gg	16	11.31	3.962	0.990

Table 3: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post-test	Equal variances assumed	4.948	0.034	-0.903	30	0.374	-1.563	1.730	-5.096	1.971
	Equal variances not assumed			-0.903	26.816	0.375	-1,563	1.730	-5.114	1.989

Table 4: Group statistics

	Students' Group	N	Mean	Std. Deviation	Std. Error Mean	Sig.	t
One month post-intervention	Game -gg	16	8.69	5.747	1.437	0.319	0.978
	Traditional -tg	16	6.81	5.076	1.269		

Table 5: Item Statistics

Subcategories of IMMS	Minimum	Maximum	Mean	Std. Deviation	N
1. Attention: 12 questions	3.08	3.58	3.3698	0.17205	16
2. Correlation: 9 questions	2.67	3.44	3.0694	0.21802	16
3. Confidence: 9 questions	2.57	3.89	3.2014	0.30149	16
4. Satisfaction: 6 questions	3.00	3.83	3.3646	0.27365	16
5. Total: 36 questions	2.97	3.56	3.2517	0.15163	16