The Race to Nuclear Supremacy: Classroom Games as Motivation for Student Learning

Abraham Ramsés Velázquez Kraff, Elsa Catalina Olivas Castellanos and David Alejandro Duarte Moroyoqui
Tecnologico de Monterrey, Hermosillo, Mexico[1,2,3]

abraham.velazquez.kraff@tec.mx[1]
cat.olivas@tec[2]
david.duarte@tec.mx[3]

Abstract: The use of games in education is applied in classroom settings from all academic levels. More importantly, games can motivate student learning in courses that depend heavily on evaluation and comprehension. The number of digital games available to enhance learning outcomes while motivating student-learning are overwhelming. Nonetheless, access to such content can be costly and limited to academic institutions that lack funds and technology. In this paper, we analyzed how a set of magnetic spheres paired with games motivated student learning in courses across 2 multicultural classrooms (Physics and Social Studies). By designing a session about the atomic bomb in a history course, professors from both History and Physics used a set of small magnetic spheres and Albert Einstein's equation E=mc2 to complement student learning in a history classroom to comprehend a topic, by using components of the magnetic spheres as an analogy of the nucleus of an atom, where the magnetic force between spheres represents the weak nuclear force. We explained the nuclear fission phenomenon and the history behind this discovery in a more hands-on approach. With this analogy, a game was designed, in which students after having taken a lecture on the history of nuclear fission and an overall explanation of Albert Einstein's formula, simulated building the atomic nuclei of radioactive elements by adding a pair of neutrons to quantify the energy released when separated as individual particles. After completing the game-based activity, we conducted a series of surveys among students to 1) analyze students' perception of the learning process during multidisciplinary classes with classroom games and 2) identify attitudes towards subject comprehension through classroom games. The experiment was carried out in sessions of 50 minutes per group. The participants of the case study were students from a private education institution in the northwestern region of Mexico (State of Sonora). We examined how these game-based activities were perceived by the students regarding their motivation to learn. In order to enhance the motivation for student learning, multidisciplinary collaboration should be included in the design process of the curriculum the school offers to its students.

Keywords: Higher education, Educational innovation, Game-based learning, Social studies, Nuclear fission, Tec 21 Educative Model

1. Introduction

Educational institutions and professors around the world have strived to provide a quality education for their students at each academic level. The standard that these must meet is not only to respond to international organizations, national authorities, and experts but to students as well. The challenges that the education system has endured during these last few years due to the global pandemic, and the remote learning environments among other difficulties have had a lasting impact on how students receive their information and on how professors must meet them in the middle.

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), the education systems do not present the necessary tools, connectivity nor technical skills, and competencies that the digital age requires for the fast-paced globalized post-pandemic world of today (2023). In the case of Latin American countries, one of the expected targeted goals out of the 17 Sustainable Development Goals (SDGs) is Goal #4: Quality Education, which looks to achieve inclusivity in education and learning opportunities for all around the world and across different academic levels.

Critical thinking skills, which are promoted in Social Sciences, and Mathematics (which are aligned with physics courses); the United Nations reports that "6 out of 10 children and adolescents are not achieving a minimum level of proficiency" (2023) in such competencies. By including methodologies in the learning process that aim to motivate and engage student learning, such SDG can be achieved by 2030 with the aid of professors and institutions alike.

An experiment has already been carried out in which game techniques and project-based learning methods were used during a physics lecture in a group of 34 9th-grade students to examine the impact these games have on their physics achievements, which was measured through tests, and a questionnaire (Baran, M, et al., 2018). The experiment was conducted over a period of 5 weeks in which students had to design game tool projects according to a designed topic. The group was divided into an experimental group consisting of 21 students and a control group consisting of 13 students. Before the experiment, no significant difference was found between the experimental and the control group in terms of knowledge. However, after the 5-week period, an end-test was administered, and it was determined that students who participated in the experiment achieved significantly higher scores than those who did not participate.

Some factors that affect students' performance are the lack of interest in learning, the reduced number of hours that STEM programs offer, and the lack of resources available such as laboratories and learning playgrounds to promote engaging learning activities.

In order to understand what drives a student's desire to learn so it's possible to propose a new educational system, we conducted research to analyze two factors: the student's perception of the learning process using classroom games in multidisciplinary classes and the students' attitudes towards comprehending the subject via games. The experiment was conducted on 50 students, which were separated into an experimental group of 25 students and a control group of 25 students. The control group was given a lecture on the nuclear fission phenomenon, a brief explanation of Albert Einstein's formula (E=mc2) and how to quantify the energy released, given several atoms and calculating their mass. The experimental group, besides the theoretical lecture, was also provided with a set of magnetic spheres to simulate the construction of an atomic nucleus in order to analyze how it would influence the learning process while being taught physics through a game.

This is a challenging task because even though students have displayed more motivation towards learning when exposed to games during a lecture, sometimes it is hard to conduct these experiments due to the time constraints and lack of economic resources to provide the students with the appropriate games and learning tools and it is necessary to have the required means to help students grow more enthusiastic towards learning STEM-related topics.

2. STEM Education in Mexico

In Mexico, Science, Technology, Engineering, and Mathematics (STEM) sciences are part of the basic education curriculum (primary, middle, and high school). However, the distance between innovation, research, and science development and the education system is increasing. This is due to several reasons, being one of them the low number of students with quality performance in sciences, which can be explained by the decrease in hours that STEM sciences, the lack of physical laboratories in schools to promote such sciences and experiments, the implementation of age-old methodologies that continue to produce a low number of higher education (HE) student, among other aspects (Flores-Camacho, 2012). He notes that it is not only a student-performance problem in the sciences and multidisciplinary skills, but it becomes a research production one (or lack thereof); where the scientific community continues to grow in age and not in number due to the low amount of human capital that is formed and stays in the country.

The country has attempted to increase the number of students motivated to begin a career in the STEM sciences. For example, in 2011, the *Secretaría de Educación y Cultura* (SEC) began a program called *"Síguele, caminemos juntos"* in public high schools across the country. The program's target was to promote and accompany students in their decision-making toward their undergraduate studies in a STEM field. It aimed to promote the participation of girls in sciences as a vocation in the country (Macias Gonzalez, Sánchez Carracedo & Salán Ballesteros, 2021). According to UN Women (2022), women represent less than half of the population that studies a STEM career in Higher Education. In Latin America and the Caribbean, the presence of women in STEM is still the minority in most of the fields. In the case of Mexico, they are also the minority in the scientific community and the *Sistema Nacional de Investigadores* (SNI) as well. In summary, Mexico lacks participation in STEM sciences due to several factors and to the lack of motivation and/or guidance that mostly occurs in the formative education levels of students.

There are several dilemmas that science and research face in the country, but we are only tackling one in our study: how to promote, engage and motivate student learning in multidisciplinary courses by using educational games. By doing so, we aim to motivate more students to engage and explore STEM areas as possible undergraduate studies in Mexico.

2.1 Classroom Games

Whitton & Langan (2019) have mentioned that the 'seriousness' in a student's academic trajectory becomes higher and the creativity and playfulness of learning decreases. Such seriousness can become a limitation to creativity, innovation, and motivation. Álvarez-Herrero and Valls-Bautista (2021) also explored classroom games in a science setting. Creating stimulating and playful learning environments can be inviting to students to engage more in their learning process. However, the authors also note that there is a discussion if there need to make seriousness and playfulness, especially at a HE level (p. 9).

Wiggins previously noted the importance of further research to identify in what capacity classroom games can enhance motivation among HE students (2016). He pointed out that gamification and game-based learning should be thoroughly researched and promoted to increase interest in STEM areas. Such game-based learning can be seen as an integral part of the curriculum or as an added element to aid in the learning process at the HE level. Most classroom games nowadays are located on digital platforms or online. We understand that most students are capable and well-versed in digital games but most schools in Latin American and Caribbean countries do not have the proper funding nor infrastructure to obtain such equipment, teacher training, or licenses to implement them in their classrooms. In the case of Mexico, public high schools and HE institutions also lack such equipment and proper skills from professors to handle, design and conduct their courses through or with the use of them. In some cases, even private institutions do not have enough resources to fund such technology, nor do they consider classroom games as part of their academic activities. However, the learning process goes together with play, creativity, and imagination.

When referring to multidisciplinary courses or activities, the use of digital games in Mexico is very limited. The use of virtual classrooms, which was put to work during the global pandemic caused by Covid-19, has been previously introduced to HE students. However, the implementation of digital classroom games continues to be limited due to several reasons (lack of funding is one of the main reasons). In the case of Mexico, to implement classroom games educators must think outside of the box and use the resources they have available to them (whether they are physical material, creativity, or funding).

2.2 Student Motivation

For the Organization for Economic Co-operation and Development (OECD), student motivation can lead to better overall outcomes. It states:

> *"Motivation to learn is another very important ingredient of achievement, both in school and in life. In many cases, individuals with less talent (...) are more likely to succeed than those who have talent but are not capable of setting goals for themselves" (2016).*

For Jääska (et al., 2022), student motivation at a Higher Education level is a critical component that needs to be seen from diverse perspectives, since it touches on various actors and key components. For Liu, Bridgeman & Adler (2012), student motivation does have a positive impact on students' academic performance. In sum, it does matter how HE institutions provide the proper tools and environment so they can achieve positive learning outcomes.

3. Methodology

In this qualitative study, we used an exploratory approach to analyze students' perceptions regarding the use of educational games in a multidisciplinary setting. In addition, we used Franco-Mariscal, Oliva-Martínez, & Almoraima Gil's (2015) statements from their validated survey on students' perception of the use of educational games in a chemistry course. We modified them to include multidisciplinary courses (Physics and Social Studies). Since the session included information regarding the use of some periodic table elements (Uranium and Plutonium) and some basic equations, our session consisted of several parts from other disciplines as well (Chemistry and Mathematics).

We conducted the same activity in two different groups with variations: in group 1, students only had the multidisciplinary session and had the activity of solving equations without the educational game; meanwhile in group 2, students that the multidisciplinary session and the activity of equations and the added element of the educational game with the magnets to represent the protons and neutrons. In both groups, students worked in teams of five to collaborate on the quantifications. In addition, the students from both groups also compared the calculated energy to the detonation energy of one kilogram of dynamite. This to know how many times greater is the fission energy concerning the destructive capacity of dynamite.

Both groups were formed by second-semester high school students from a private institution in the northwestern region of Mexico, in the State of Sonora. Tecnologico de Monterrey is a private university based in Monterrey, Mexico. Tecnológico de Monterrey was founded on September 6 in 1943 by Eugenio Garza Sada who obtained a bachelor's degree in civil engineering from the Massachusetts Institute of Technology (MIT). According to Qacquarelli Symonds (QS) Latin America University Rankings 2023, Tecnologico de Monterrey is Mexico's number one university and fourth in Latin America. The institute was evaluated among 429 universities from across 20 countries and has been ranked number one in Mexico for four consecutive years with a score of 94.7 out of 100.

The institute implemented a new education model named Tec 21 Educative Model during the 2019-2020 period, which is a challenge-based model. It is also a very flexible model which allows students to explore different fields of study and specializations.

In our study, Group 1 consisted of 21 participants, while in Group 2 there were 19. In Group 1, 11 participants were female and 9 were male; while in Group 2, 2 were female, 18 were male and 1 participant preferred not to disclose gender. In total, 13 participants identified as female, 27 as male (the majority in the study), and one did not disclose.

The proper consent forms to participate in the study were provided via email, as well as a disclaimer where it stated that their identities would not be revealed, nor would their answers affect their grade performance in any way whatsoever.

To create the activity, we considered the prior knowledge students had of physics (middle school education) and included in our activity a brief review of the periodic table and its elements, specifically the ones that were used to design the first atomic bomb (Uranium and Plutonium). The activity consisted of understanding the nuclear fusion phenomenon from its origins. This meant that the activity consisted of three parts. First, we provided historical information about the World War II period, the actors, the motivations, the interests, and the alliances that were formed. This part also touched on the historical side of the main physicists (Lise Meitner and Otto Hahn) involved in the discovery of the elements, the formulation, and the creation of the atomic bomb.

The second part consisted of explaining the nature of the chain reaction known as the atomic bomb. This was done by providing an insight into the academic contribution of the work done by Albert Einstein (1905) on the relation between energy and mass (to quantify the fission energy in the separation of the atomic nucleus). Finally, the third and last part was the actual activity that students (in teams) needed to do. In this part, students had to convert the atomic mass of the atom of Uranium or Plutonium to kilograms, thus using it Einstein's formula. To do so, we provided an explanation and an example of how to convert the mass to kilograms. Once the first two parts of the activity were presented, students had to complete the last part in teams of five participants.

Both groups had their sessions in the same week. Group 1 had their activity at the beginning of the weekday (on a Tuesday) and Group 2 was in the middle of a weekday (on a Thursday). In Group 1, the activity consisted of two moments: one was the historical and physics aspect of the explanation of the atomic bomb of World War II; while the other moment was the quantification of the fissionable mass of one group of atoms (Uranium or Plutonium). In the first group, we did not introduce the educational games aspect into the session.

In Group 2, the same two moments as of Group 1 were applied. Nonetheless, the educational games aspect was introduced in the second moment with a magnetic sphere kit to simulate the construction of an atomic nucleus. The kit was chosen to represent the physical interactions that occur in a nucleus of an atom. The force of magnets represented the nuclear force between protons and neutrons. Meanwhile, the colors of some of the magnets represented electric charge (in the case of protons) or no charge (in the case of neutrons).

4. Results and Discussion

We analyzed the information from the students retrieved from the survey we designed to analyze students' motivation and their attitudes toward the use of classroom games in a multidisciplinary environment. In this case, such an environment was made up of the disciplines of Physics and Social Sciences (history).

The target of the activity was to offer students the scientific and historical context of a transcendental event in the history of mankind, such as the atomic bomb, and the technological development of the world. By doing so, we wanted to comprehend their perception regarding multidisciplinary classes with classroom games and analyze the attitudes they had towards subject comprehension by way of classroom games. We are convinced that knowledge can be better approached when tackling problems or situations from a multidisciplinary perspective, regardless of the difficulty of the subjects of study if the student is adequately motivated towards active learning. In the results reported by Herbert James Banda y Joseph Nzabahimana (2022), they argue that by using technologies like simulations for physics teaching students will become more motivated to learn, which leads us to discuss the contribution of this work, since implementing a low-cost game without the need to use a technological application, we obtained extremely positive results regarding the motivation and perception of our students. On the other hand, Christina A. Bauer, Veronika Job & Bettina Hannover (2023) state that there is a social and cultural bias in first-generation students where they are less talented. However, the idea that success should be measured by work and not only by innate abilities is stated, also mentioning that for the teaching-learning process, it is fundamental to be able to create a great motivation for teaching these subjects since we strongly believe that science is universal and that neither the social conditions nor cultural conditions matter, but the motivation that we consider necessary does.

4.1 Students' Perception of the Learning Process With Games in the Classroom

Regarding the students' perception, statement 10 for group 1 (*Educational games can contribute to me seeing physics as an important area in my life*) showed that 12 of 19 participants agreed with it. While 6 fully agreed and 1 was undecided. In group 2, this statement showed that 9 of 21 participants agreed with it. While 8 fully agreed and 4 were undecided.

In the explanation before carrying out the activity, it was repeatedly mentioned that the race to dominate nuclear energy was not only the development of a destruction bomb but also a new way of producing electrical energy, through the process of the operation of nuclear reactors. This action had an impact on the development of emerging technologies for the processes of burning fossil fuels, which gave strength to the results obtained in this question.

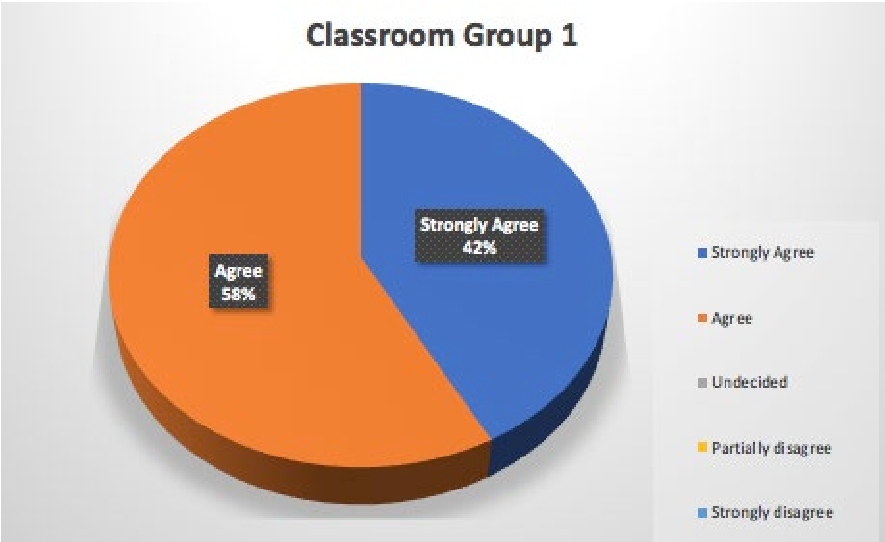

Figure 1: ***Pie chart representing answers from statement 10 (*****Educational games can contribute to me seeing physics as an important area in my life)** ***from participants of Group 1***

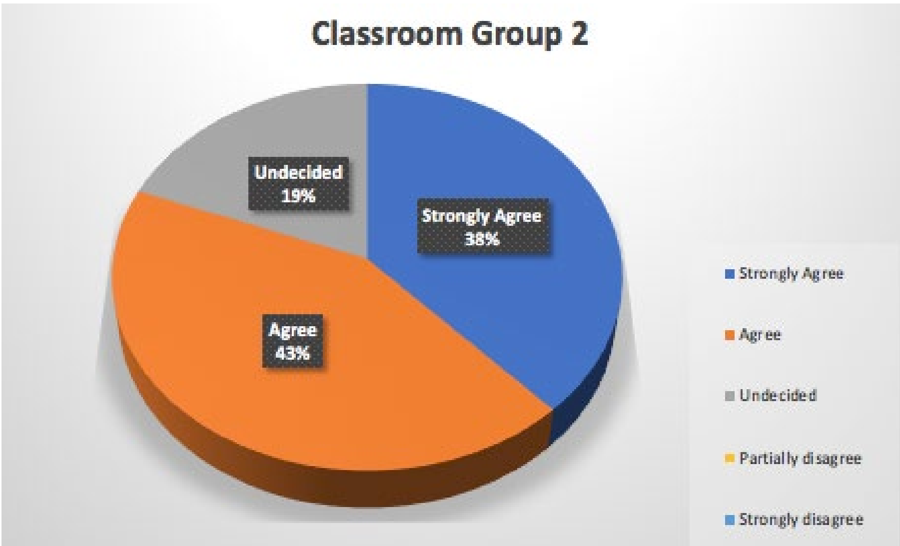

Figure 2: ***Pie chart representing answers from statement 10 (*****Educational games can contribute to me seeing physics as an important area in my life)** ***from participants of Group 2***

On the other hand, statements 1 and 3 for group 1 (The use of educational games makes it easier for me to study, educational games have helped me to gain a better understanding of the multidisciplinary topic) were very positive, showing that 12 out of 19 participants were in total agreement and 7 agreed in statement 1. While, for statement 3, 9 participants were in total agreement and 9 agreed, leaving only one undecided participant.

Now, analyzing statements 1 and 3 for group 2, 10 participants stated that they agreed, 10 stated that they agreed, and 1 participant was undecided regarding statement 1 (The use of educational games makes it easier for me to study). While for statement 3 showing that 8 participants fully agreed, 12 participants agreed, and 1 participant was undecided. This gives us a better idea of the scope and impact they have on perception and understanding among students by introducing activities that invite the use of educational games in the classroom, specifically in a multidisciplinary activity (in this case Social Sciences and Physics).

All survey statements (see Table 1) were represented and analyzed according to our main objectives in this study (see Figures 3 and 4 below).

Table 1: Participants of groups 1 and 2 survey

1. The use of educational games makes it easier for me to study.
2. The educational games had clear and easy-to-follow instructions. Everybody knew what to do.
3. Educational games have helped me to gain a better understanding of the multidisciplinary topic.
4. Because of the use of educational games, I like multidisciplinary courses.
5. I found educational games attractive.
6. I consider educational games to be an appropriate tool for a better understanding of multidisciplinary concepts.
7. I find educational games to be an appropriate way to learn in multidisciplinary courses.
8. By using educational games some multidisciplinary content can be made interesting and even enjoyable.
9. I think that educational games are very entertaining.
10. Educational games can contribute to my seeing physics as an important area in my life.
11. I felt more motivated to participate in classroom tasks when we used educational games.

Table 2: Instructions of exercises for participants

Based on the previous model, determine the released energy produced by a nucleus of a fissile element putting into practice Einstein's formula of the mass-energy relationship. Document the entire calculation process that your team followed to determine the energy. Choose between one of the elements ((Uranium or Plutonium) from the periodic table which will be its object of study.
Determine the energy that would be released by your uranium or plutonium nucleus considering that 1% of its atomic mass was converted to energy.
If it has 10,000 nuclei and that each of them released the energy calculated in the previous part, how much energy would be released by all of them? How much energy would that be compared to the energy released from TNT?

In addition, a statistic was made with the results that we obtained from graphs 3 and 4 (see Figures 3 and 4). For Group 1, the mean values of the 11 statements in Table 1 were obtained: agree 10.1818, strongly agree 7.9090 and undecided 0.9090, while the variability was 3.7636 concerning the mean and with a standard deviation of 1.94. This implies that 18 participants provided positive responses and only 1 participant was within the negative response range. In Group 2, very similar results were obtained with an average value of: agree 9.3636, strongly agree 9.1818, undecided 2.2727, and partially disagree 0.1818. While the variability of these results was 2.8545 concerning the mean and with a standard deviation of 1.6895. This means that a total of 19 participants provided positive answers while only 3 participants provided negative answers.

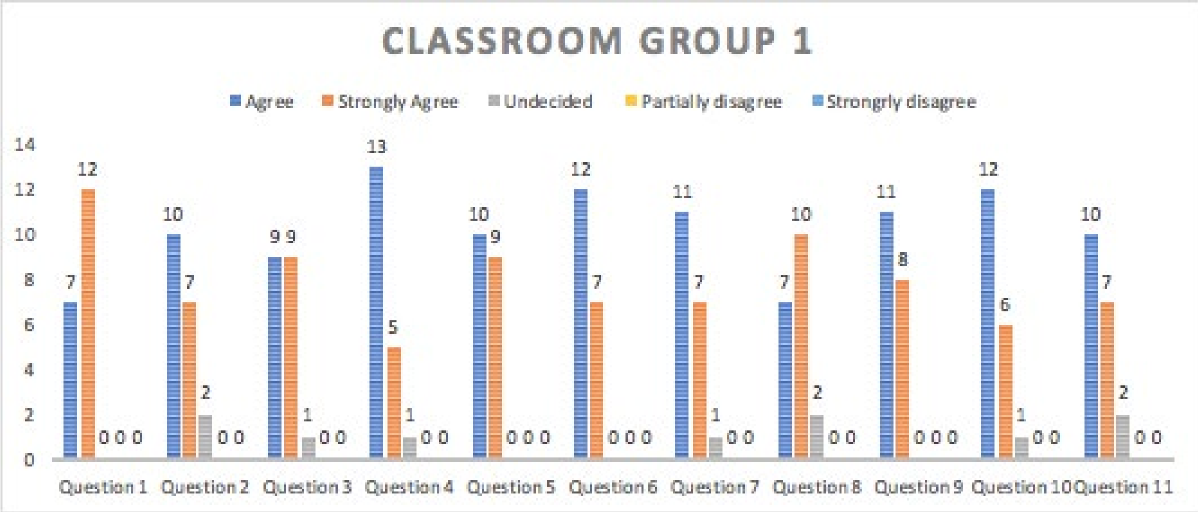

Figure 3: Representation of results of the statements in Table 1 from Group 1

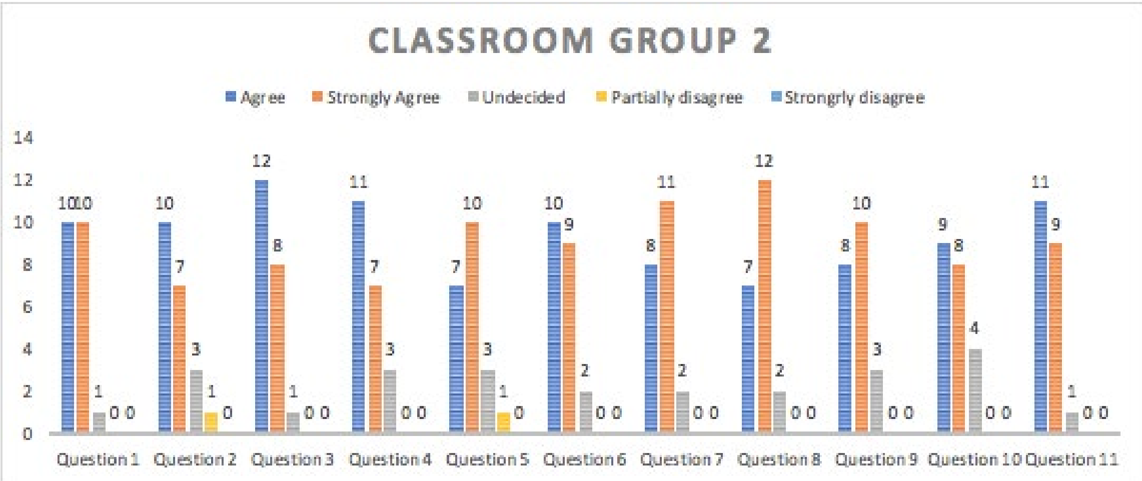

Figure 4: Representation of results of the statements in Table 1 from Group 2

4.2 Attitudes towards understanding the subject through games in the classroom

Regarding attitudes that participants mentioned towards subject comprehension, both groups agreed that the use of classroom games was useful and positive towards their learning process. Even participants from Group 1, who did not use the actual game of magnetic spheres to create the nucleus of an atom, agreed that it would have been good to have such material with them when exploring the subject. Meanwhile, participants from Group 2 had to also represent their model with magnetic spheres (see Figures 5 and 6).

Figure 5: Pictures of the magnetic spheres as an analogy of the nucleus of an atom from Group 2

Figure 6: Pictures of the magnetic spheres as an analogy of the nucleus of an atom from Group 2

In statement 1 of Table 1, 62.2 percent of participants mentioned that they fully agreed that game-based learning aided them in their learning process; and the other 36.8 percent agreed. The possibilities for designing a completely innovative approach towards student learning in the institution emerges: a multidisciplinary course design instead of the traditional course is possible and can be effective among participants.

Statement 2 was fundamental since 36.8 percent of the students agreed that they fully knew what they had to do in the activity, while 52.6 percent agreed with what was being asked to solve and only 10.5 percent were unclear about the explanation. We consider it important due to the complexity of the topic and especially the age of the students. We analyzed their answers from the activity as well as the answers they provided in the survey and determined that their perception of not only the classroom game but the multidisciplinary approach to the lesson was a positive one.

We must note that both groups of participants were given the same information, however, we believe that the activity could have been divided into two sessions per group: one benign that of the historical context and the explanation of the model; and the second one would be dedicated only to the elaboration of the equations and creation of the model itself with the magnetic spheres. This can also change the outcome of students' perception and overall experience with classroom games.

5. Conclusions

In this paper, we analyzed if classroom games in a multidisciplinary environment can motivate students' learning process. Also, we analyzed what attitudes students had toward their learning through classroom games. While we saw overall interest in this multidisciplinary approach to learning with games, only one group of participants managed to 'construct' the model with the magnetic spheres. The initial idea we perceived from the group that did not have a classroom game but only the exercises and the session, was that they perceived the equations as a 'game' or a competition of who can come up with the answers the fastest. However, after questioning the participants on this matter, they did not see the equations as a game but did see them as a fun or playful element of the multidisciplinary session.

The survey conducted was designed to analyze the perception and attitudes of the participants towards learning through educational games, group 1 had a total of 19 responses. The results of the survey displayed that an average of 13 participants agreed and 5 strongly agreed with the statements, while an average of only 1 was undecided. Group 2 had a total of 21 responses. An average of 9 participants agreed and 9 strongly agreed with the statements while 2 were undecided and only a small fraction less than 0.2 disagreed with the statements. Even though group 2 displayed a higher rate of negative responses towards the use of classroom games, we could observe that students displayed more interest at the beginning of the activity. However, their sense of interest began to decrease throughout the development of the activity.

The participants saw the value that classroom games can bring to their learning process, they perceived them as an added component to a session and had a positive attitude overall towards using games to learn and to be motivated in the classroom.

We understand that this does not apply to the overall population of students in an institution but suggest enhancing and modifying our initial study with more proper materials and a two-part session where students and professors alike can have more time to do both parts of the multidisciplinary activity. Also, if necessary, we might add an evaluation of knowledge at the end of such a session to identify if their academic performance on the subject improved, changed, or was maintained with and without the use of classroom games.

The authors of this paper believe that some factors could be corrected and considered more thoroughly when implementing the activity on another occasion, such as using technology (Virtual Reality (VR) or Augmented Reality (AR)). This is to increase the perception, attention, and motivation of learning the current model known as the atomic nucleus. Also, we suggest that activities such as the one described should be implemented among private and public education students to compare the results among both participants.

Declaration of interest

This is to acknowledge that the authors report there are no competing interests to declare.

Acknowledgements

We want to acknowledge the financial and technical support of the Writing Lab, Institute for the Future of Education, *Tecnologico de Monterrey*, Mexico, in the production of this work. We also acknowledge the support of the *Centro de Desarrollo Docente e Innovación Educativa* (CEDDIE) at *Tecnologico de Monterrey,* Sonora Norte Campus, and its director Eduardo Rodriguez Álvarez. Finally, we would like to thank Lucia Canseco (Director of PrepaTec), and Maria Teresa Villegas Bailón (Director of the Academic Department of Sciences at PrepaTec), for their continuous support.

References

Álvarez-Herrero, J.-F., and Valls-Bautista, C. (2021). The Game as a Strategy for Learning Chemistry Among High School Students. *European Journal of Science and Mathematics Education,* 9(3), 80-91.

Banda, H.J., Nzabahimana, J. The Impact of Physics Education Technology (PhET) Interactive Simulation-Based Learning on Motivation and Academic Achievement Among Malawian Physics Students. *J Sci Educ Technol* 32, 127–141 (2023).

Baran, M., Maskan, A., & Yaşar, Ş. (2018). Learning Physics through Project-Based Learning Game Techniques. International Journal of Instruction, 11(2), 221-234.

Bijlsma, H. (2021). The Quality of Student Perception Questionnaires: A Systematic Review. In: Rollett, W., Bijlsma, H., Röhl, S. (eds) Student Feedback on Teaching in Schools. Springer, Cham.

Christina A. Bauer, Veronika Job, and Bettina Hannover. (2023). Who gets to see themselves as talented? Biased self-concepts contribute to first-generation students' disadvantage in talent-focused environments. Journal of Experimental Social Psychology, 108, 1-14.

Einstein, A. (1905). Ist die Trägheit eines Körpers von seinem Energiegehalt abhängig? *Annalen Der Physik*. 18:639.

Eltahir, M.E., Alsalhi, N.R., Al-Qatawneh, S. *et al.* (2021). The impact of game-based learning (GBL) on students' motivation, engagement, and academic performance in an Arabic language grammar course in higher education. *Educ Inf Technol* 26, 3251–3278.

Flores-Camacho, F. (2012). *La enseñanza de la ciencia en la educación básica en México*. INEE.

Franco-Mariscal, A. J., Oliva-Martínez, J. M.,and Almoraima Gil, M. L. (2015). Students' perceptions about the use of educational games as a tool for teaching the periodic table of elements at the high school level. *Journal of Chemical Education*, *92*(2), 278-285.

Jääska, E., Lehtinen, J. Kujala, J. and Kauppila, O. (2022). Game-based learning and students' motivation in project management education. *Project Leadership and Society.*

Liu, O. L., Bridgeman, B., and Adler, R. M. (2012). Measuring learning outcomes in higher education: Motivation matters. *Educational Researcher*, *41*(9), 352-362.

Macias Gonzalez, G. G., Sánchez Carracedo, F., and Salán Ballesteros, M. N. (2021). C*ómo fomentar vocaciones en infantes y jóvenes en México para cursar carreras STEM.*

OECD. (2016). Student engagement and motivation. *Review education policies.* OECD.

ONU MUJERES (2022). *Necesitamos más mujeres en carreras STEM*. ONU MUJERES América Latina y el Caribe.

Portnov-Neeman, Y. and Barak, M. (2013) Exploring Students' Perceptions about Learning in School: An Activity Ramírez-Montoya, M.S.; Castillo-Martínez, I.M.; Sanabria-Z, J.; Miranda, J. Complex Thinking in the Framework of Education 4.0 and Open Innovation—A Systematic Literature Review. J. Open Innov. Technol. Mark.Complex. 2022, 8, 4. Theory Based Study *Journal of Education and Learning* 2: 9-25.

TECNOLOGICO DE MONTERREY (2023). Esto es lo que hay detrás de la implementación del Modelo Tec 21*. CONECTA.*

TECNOLOGICO DE MONTERREY (2023). Ranking QS: Tec de Monterrey, la universidad 1 en México y 4 de Latam. *CONECTA.*

UN. (2023). *Sustainable Development Goals: Quality Education.* UN.

UNESCO. (2023). *UNESCO's action in education: Our vision.* UNESCO.

Whitton, N., and Langan, M. (2019). Fun and games in higher education: an analysis of UK student perspectives. *Teaching in Higher Education, 24*, 1000 - 1013.

Wiggins, B. E. (2016). An overview and study on the use of games, simulations, and gamification in higher education. *International Journal of Game-Based Learning (IJGBL)*, *6*(1), 18-29.