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The contribution of online gaming in Engineering education

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Abstract. The motivational force that is attributed to games in general is primarily responsible for the rise in popularity of games as educational tools. The study looks at the function that various types of motivation play in educational gaming as well as how the context of the game and the lesson plan affects students' desire to participate in game play. According to our research, numerous motivational forms can coexist among students who play games, and the interaction between game attractiveness, game learning, and game operativeness can help to explain how these motivational forms evolve. The use of video games in higher education is expanding in the engineering field. The need for virtual labs and technologically advanced experiential learning aids like digital games is anticipated to increase as a result of the new COVID-19 regulations and the shift to virtual learning. An analysis of current techniques in digital game-based learning for engineering education is presented in this research. The most significant benefit is that it offers understanding into how digital game-based learning is applied across many engineering specialties. It also gives scholars and practitioners information about pertinent publications, conferences, games accessible, study designs, and evaluation techniques used in the area of digital game-based learning for engineering. The review's findings point to an increase in the study on games' distribution and, maybe, the application of games in engineering education.

Keywords. Educational game; virtual lab; digital game; virtual learning; engineering education;

1. Introduction

The educational and research communities have shown a great deal of interest in game-based learning as a pedagogical approach that may provide an engaging and dynamic learning environment for students. Games have found extensive use across a variety of academic subjects since there is increasing evidence that they may improve cognitive, emotional, and psychomotor abilities (Papanastasiou G., Drigas A., et al., 2017;Connolly et al. 2012). Contrary to traditional lectures, it is thought that game-based learning methodology encourages students' active engagement in the learning activities. Structured or organized play includes entertaining games with clear objectives (Klopfer, Osterweil, and Salen 2009; Drigas A. & Mitsea E., 2020). Other components of games, outside objectives, typically include fantasy, rules, difficulty, feedback, rivalry, collaboration, control, and storytelling (Prensky 2003). Despite the fact that these components define a game, not every game has them. Learners can develop desired abilities while having fun when educational materials are integrated into gaming settings (Drigas A. S. and Pappas M.A., 2015).

Digital games, which require the use of electronic devices like computers and mobile phones, are utilized in schools alongside non-digital games like board games. Other times, to make school exercises more interesting, gaming components are added. Gamification is the term for this (Plass, Homer, and Kinzer 2015; Fotoglou A., Moraiti I., Drigas A., et al., 2022). Despite the usage of these games and gamification in engineering education, digital games are becoming increasingly popular (Bodnar et al. 2016; Bodnar, Liauw, and Sainio 2021). The development of digital games to offer highly dynamic learning settings for players, whether in single-player or multiplayer games, has been driven by technological advancements and the relatively low cost of devices (Slimani et al. 2018).

According to Bahadoorsingh, Dyer, and Sharma (2016), digital game-based learning (DGBL) is an instructional strategy that incorporates educational materials into video games. It is purportedly employed in a variety of topic areas (Boyle et al. 2016). Educational or serious games and entertaining games are the two main categories of digital learning games. Games made particularly for enjoyment, amusement, or entertainment, are referred to as digital entertainment games (DEG). On the other side, serious games and educational games are generally created with other goals in mind than merely having fun. These games are intended to encourage learning and behavioral improvements (Connolly et al. 2012). Even though DEGs and educational games have been proven to be successful learning environments, each is thought to have some benefits and restrictions when used as a teaching tool. DEG games tend to be high-end, incredibly interesting, and easily accessible since they are typically produced by gaming firms with higher resources with the intention of producing money. On the other hand, DEG games can be pricey, have complicated user interfaces, have high learning curves, and frequently do not align with curricular goals (Whitton N., 2009). On the other side, educational games are created with learning in mind, putting emphasis on desired learning outcomes throughout the design process and frequently having strong connections to the curriculum (Drigas A. & Mitsea E., 2020).

The creation of these games can be costly and time-consuming, and they may not interest players as intended. Many DEG games now include creative engines as a compromise, enabling adaptations for instructional purposes (de Freitas S., 2006). Various engineering disciplines have been taught and trained using entertainment games (Bahadoorsingh, Dyer, and Sharma 2016), educational games (Smith and Chan 2017), and modified DEG games (Coller and Scott 2009), according to studies. There are many different types of games, including simulations, role-playing games, puzzles, and action games. These games are available as both digital and analog games. According to studies (Boyle et al. 2016; Connolly et al. 2012), simulation games are the most well-liked ones for instruction and training since they are made to mimic real-world scenarios while incorporating game-like characteristics like collaboration and competitiveness. They are thought to have promising uses in engineering education as well (Deshpande and Huang 2011). It is advantageous to understand how these games are used for engineering education in order to give practitioners and researchers insights into their applications. This is because the use of digital games is increasing, and there is a growing need for digital educational solutions to support current remote learning activities during the COVID-19 pandemic restrictions. It demonstrates how digital games are being utilized in engineering education to help engineering students, with an emphasis on evaluating how the games affect the learning that the students display.

2. Using computer simulations for education in the engineering field

Simulated environments that replicate real-world situations in which students interact are used as teaching tools in simulations. The boundaries of this "world" are under the instructor's control, and he or she employs it to produce the intended educational outcomes. The situation is seen as reality by the students, who then interpret it. Experiential learning includes simulation. Since it adheres to constructivist teaching and learning concepts, it is an approach that works effectively. A simulation may include components from a game, a role-play, or a metaphorical activity. They are distinguished by their non-linear structure and the managed ambiguity that pupils must navigate. A simulation's success is often determined by the players' creativity and dedication (Papanastasiou G., Drigas A., et al., 2017). They encourage engineering students to apply critical and evaluative thinking. In the context of engineering education, they support idea acquisition through practical application. Student understanding of conceptual distinctions may benefit from simulations (Chaidi I and Drigas A., 2022). As they participate in the action first-hand rather than just learning about it or witnessing it, engineering students frequently find them being more intensely engaging than other activities. Academic motivation and accomplishment in elementary and secondary education have often been the focus of research on the effects of video games on learning (Kapp K.M., 2012; Deterding S., 2012; Kula A. and Erdem M., 2005). For instance, Kula and Erdem, looked at how primary school children' basic arithmetic processing skills were affected by instructional computer games. It was discovered that the educational game's impact on the 4th and 5th grade students' acquisition of fundamental arithmetic processing abilities was not statistically significant. The study did discover that following the application, students had a greater propensity to carry out intricate gathering techniques. Students have also shown support for using video games to motivate and educate them. On the other hand, Bayirtepe and Tüzün, investigated the impact of instructional computer games on the performance of primary school pupils in computer courses and their opinions of their own efficacy.

The results of the accomplishment test conducted before and after practice showed a statistically significant rise in the number of students using the game-based learning environment. The judgments of students' computer self-efficacy and success in a learning-based learning environment did not, however, differ significantly from one another. Students are seen to have a good attitude about the utilization of game-based settings in this setting where computer hardware is mastered. Although research on the use of games and simulations in engineering education has grown significantly, the number of studies is still quite small.

3. Online games and simulation for learning

Because students are already integrating technology into their spare time at a rate that schools are unable to keep up with, educational digital games have a role to play in future education (Prensky M., 2006). The report may be used as a reference to show how widely digital games and simulations are now used in education by administrators who want to push teachers to incorporate them into their regular scientific courses. With the help of an ideal multimedia tool that presents ideas in a way that is interesting, inspiring, and engaging, digital games offer the area of education with cutting-edge chances that train the learner via involvement (Reiber L.P. and Noah D., 2008; Squire K.D., 2008). Digital games can support constructivist ideas by enabling learners to participate in immersive environments and claim ownership of their learning (Barab S.A. and Gresalfi M., 2010). Computer games with built-in problem-solving opportunities provide students a risk-free environment in which to explore with the subject matter as they acquire new information (Doulou A and Drigas A., 2022). Digital games for learning can offer a dynamic, student-centered environment that fosters individualized learning by gradually integrating new information and structuring it into what students currently know.

The use of a computer-generated system to simulate the dynamic reactions and behavior of an actual or hypothetical system is known as simulation. Computer simulations are used to examine the behavior of objects or systems that, like weather patterns or nuclear explosions, cannot be easily or safely evaluated in real life. Playing video games resembles real-world situations (like business or combat), especially when used for practice or assessment. Games might be categorized as amusing simulations. Because they are affordable, repetitive, and simple to alter, simulations are the preferred teaching and learning tools (Drigas A., Mitsea E. and Skianis C., 2022). Simulation is the gradual simplification of a real-world process or system's functioning (Banks J. and Carson J.S., 1984). It is a representation of systems or processes that has established connections between system components. An educational simulation's objectives include inspiring pupils to solve problems, engage in practical learning, and construct mental models (Duffy T.M., 1996). Educational simulations depend on scaffolding, coaching, and feedback (Gençoğlu, M.T., 1999) to facilitate learning. Simulation offers unbiased knowledge about the procedures that are accessible right now and, more crucially, in the future. A simulation is a representation of an actual event, simulating an actual event with the use of a computer. For instance, a computerized flight simulator is a simulation model used to teach some aviation regulations (Papoutsi C., Drigas A. and Skianis C., 2021). The pilot will act as if he is actually on board by acting as though they are both looking at the same screen in the cockpit during the simulation. Simulator flying is both safer and more affordable than actual flight. The cheap cost, lack of hazard, and often impossibility of experimentation on real systems are the main justifications for the use of models in business and industry. Saving money and time may be achieved by testing on models that closely resemble actual systems.

4. Game motivation and the game's operativeness, attractiveness and learning

Educational games are regarded as teaching tools that enable students to take responsibility for their learning and that support experiential learning. The motivating potential of educational games is an often held belief that underlies their ability to promote learning (Bodnar C.A. et al., 2016). Educational games are anticipated to naturally encourage pupils if they are properly created. Students participate in a game because they find it to be entertaining and worthwhile**.** Learning becomes a rewarding endeavor since game play and learning are viewed as being interwoven (Ozcelik E., Cagiltay N.E. and Ozcelik N.S., 2013). Our research aims to provide a more nuanced understanding of the motivational elements of educational games used in an engineering course setting. We were particularly interested in the motivational structures present during game play and the conditions that led to their creation. It responds to previous recommendations for a more thorough investigation of the learning and motivational impacts of educational games in engineering applications (Deshpande and Huang 201; Bodnar et al. 2016). Its contribution to these arguments is twofold: first, it demonstrates that several motivating forms may coexist in game play, and second, it demonstrates that their appearance is caused by the interaction of game attractiveness, game learning, and game operativeness.

The findings of Hartmann and Gommer study, which were drawn from seven example games, put the exaggerated faith in the ability of games to motivate students and, in turn, the learning efficacy of games in engineering education more into perspective. When students play instructional games, they discovered that several incentive modalities may coexist. For both years, it was possible to identify self-determined motivational forms (intrinsic motivation and recognized regulation) in every game as well as non-self-determined motivational forms (external regulation and amotivation) (Hartmann A. and Gommer L., 2021; Drigas A., Mitsea E. and Skianis C., 2021). For each game, the pupils' positive and negative the so-called self-determination index (SDI) (Hartmann A. and Gommer L., 2021) scores are calculated. The use of games in the classroom does not always result in students who are intrinsically driven, as past research from other educational areas has shown. Overall, these findings are consistent with that earlier study (Gunter G., Kenny R.F. and Vick E.H., 2006). The coexistence of various types of motivation in all seven games, despite the fact the games were not compared to other teaching tools, implies that, even in engineering, educational games may not always be more motivating than other teaching methods. The findings also indicate that the distinction between computer and board games is irrelevant (Hartmann A. and Gommer L., 2021). The popularity of computer games among the younger generation may encourage the use of games in education, but it does not ensure that these games will motivate pupils. The seven games exhibit variations in their overall motivating impact, with a range of 3 (Game 3) to 28 (Game 7) of the median SDI ratings. The mechanics of the games might be one reason for the discrepancy. Game mechanics that support self-determined motivating forms are more prevalent in the games with higher SDI ratings (Games 6 and 7). The sort of game mechanics appears to be less important because they are shared by other games, but not by all of them taken together. We contend that in order to maximize the motivational potential of games, it is more crucial to integrate game mechanisms that meet each of the three fundamental human wants (autonomy, competence, and relatedness). This might be accomplished for the games 6 and 7 through ownership and role play (autonomy), competitiveness and teamwork (relatedness), advancement, strategy/planning, and competence (Hartmann A. and Gommer L., 2021). The coexistence of several incentive strategies, however, demonstrates that focusing just on the game mechanics would not guarantee interested pupils.

The motivating impact of games on pupils is a result of how well-designed, appealing, and educational they are (Hartmann A. and Gommer L., 2021). Game 6 had the highest ranking from both years' focus group participants, who all were students. The key factor cited for this was the appeal of the game. The maintenance work bid rounds were viewed as difficult and realistic. As contractors, the students were able to feel and experience the bidding process firsthand. The game was more alluring in the eyes of the students because of the intense interaction between and within contractor teams as well as the immediate evaluation of team performance following each round of bidding. To comprehend the game's concepts and regulations, however, a lengthy introduction and test round were necessary, which reduced the game's appeal and educational value and even resulted in a single SDI score below zero (Hartmann A. and Gommer L., 2021). The focus group participants' emphasis on game attractiveness, learning, and operability led to a difference in how the other games were ranked in both years.

Table 1a: Game operativeness, attractiveness, and learning findings

	Game 1: GasSolution	Game 2: RiskSwitch	Game 3: RAMSes	Game 4: Highway Stakes
Game operativeness	– Instructions were insufficient to start playing – Lack of explanation at higher game levels	– Required careful reading at the beginning – Stimulation of discussions if played in pairs	– Missing clarity of goals at the beginning due to time restrictions – Different pace of teams led to idle time – Limited number of teams resulted in large teams with unequal participatio	– Required careful reading at the beginning – Stimulation of discussions if played in pairs
Game attractiveness	– Achieving high scores was perceived as challenging – Direct feedback on scores and level – Competition was triggered between students	– Dilemmas were challenging – Less dynamic due to similar decisions in a row – Less attractive due to missing direct feedback – No competition between students	– Interaction within teams high during game – Working in teams is perceived as attractive – Competition between teams facilitated engagemen – Direct feedback on tender price per round	– Dilemmas were challenging – Less dynamic due to similar decisions in a row – Less attractive due to missing direct feedback – No competition between students – Repeti on experienced because similar to game 2
Game learning	– Discussion limited to gameplayand progress – Difficulties in abstracting from game content – Missing link	– Contributing to learning due to realistic view on decision-making – Link with course content was difficult to make	– Contribution to learning because of clear link between lecture and game	– Contribution to learning through discussion after game play – Clear link with course content – Knowledge was partly available from other

	between game and course objective			courses

Note. From "To play or not to play: on the motivational effects of games in engineering education" by Hartmann, A. & Gommer, L., 2021, *European Journal of Engineering Education*, *46*(3), 319-343.

Table 1b: Game operativeness, attractiveness, and learning finding

	Game 5: AMImplementation	Game 6: RoadRoles	Game 7: BridgeGame
Game operati veness	– Difficulty to understand goals and structure of the game due to decisions lines simulated – Amount of reading was not supportive for starting game play – Excel macro of game did not work at all computers – Dependency on other team led to idle time	– Lots of information to be processed at the beginning – Many clarifying questions asked and test round needed – Idle time due to change between tender preparation and tender evaluation – Bankruptcy of contractor team led to exclusion fromgame	– Not much explanation needed to start playing – Time for playing was underestimated, not all teams could finish – Teams of 5 students are perceived as too big for having meaningful discussions
Game attracti veness	– Student were enthusiastic when moving between decision rounds – Interaction within teams during gameplay – Challenge stemmed from thinking about rationale behind decisions of another team – Feedback on decision consistency at the end	– Increased interaction within teams – Engagement through competition between contractor teams – Complexity of tender process challenged students – Direct feedback on tender success per round	– Complexity of trade-off between objective, performance and budget was challenging and stimulated discussion – Competition facilitated engagement – Direct feedback on objective, performance and budget per round
Game learnin g	– Contribution to learning through link with assignment – Feedback from game is not sufficient for learning	– Contribution to learning through realistic situation and direct experience of decisions in a tender	– Contribution to learning through discussion after game play, – Direct feedback in game is not sufficient for learning – Not much prior knowledge needed to play game

Note. From "To play or not to play: on the motivational effects of games in engineering education" by Hartmann, A. & Gommer, L., 2021, *European Journal of Engineering Education*, *46*(3), 319-343.

The educational context for games

The motivating effects of games, which are instruments employed in educational contexts, depend on the settings in which they are utilized (Proulx J.N, Romero M. and Arnab S.,2017). According to Hartmann A. and Gommer L. research, the interaction of a game's attractiveness, learning potential, and operationality leads to the creation of many motivating forms in games. The findings indicate that game attractiveness has a considerable direct impact on intrinsic motivation, but the direct impact of game learning and operativeness on intrinsic motivation is negligible. These results confirm earlier study (Garris R., Ahlers R. and Driskell J.E.,2002;) which found that game elements were the main motivators for students' motivation. The findings also imply that difficulty and engagement, in particular, are key factors in the appeal of the games to students. These results confirm our earlier claim that combining game mechanics like strategy/planning and teamwork can make games more hard, interesting, and hence appealing to students, since there is a substantial correlation between game attractiveness and game mechanics (Kokkalia G., Drigas A. & Economou A., 2016).

However, the appeal of a game by itself cannot account for the existence of other motivating mechanisms. It has a negligible direct impact on identified regulation and even negligible direct impacts on external regulation and amotivation (Kefalis C, Kontostavlou EZ. and Drigas A., 2020). To put it another way, emphasizing the appeal of the game can boost students' intrinsic drive but cannot counteract external incentive. The case study findings demonstrate that game learning, in particular, can account for the formation of several extrinsic motivational phenomena. It significantly influences identified regulation, external regulation, and motivation directly. According to Iten and Petko (2016), seems that students who played the games anticipated to learn anything from them. They learned a lot by playing the game and they would prefer stop playing if they did not learn enough while playing the game. This behavior was noticeable in Games 2 and 4, which didn't provide the players any immediate feedback on their choices (Hartmann A. and Gommer L., 2021). One implication is the inclusion of direct feedback as a game mechanic or plenary between-round feedback that enables students to extract and convey the learning directly from the game (Proulx J. N., Romero M. and Arnab S., 2017).

Additionally, the investigation showed that game allure itself might indirectly affect non-selfdetermined motivation through game-based learning. The scenarios show that students will get less learning from the game if game activities are seen as being too hard or too simple to complete since they do not correspond to their existing level of knowledge. As a result, kids lose interest in playing further and start to see gaming as merely something they have to do (Hartmann A. and Gommer L., 2021; Papoutsi C., Drigas A. and Skianis C., 2021). The knowledge diversity of student populations may be addressed by taking into account various degrees of difficulty inside a game as well as other educational techniques used prior to games (Papoutsi, C. & Drigas, A., 2016). This was seen in Game 3, when students were able to immediately link the game to the information presented in a lecture that was delivered prior to the game play (Hartmann A. and Gommer L., 2021). The findings indicate that for learning to become a personally valued game play result, an appealing game is a must. Attractive games engage and test pupils, who can more easily retain important knowledge and weed out unnecessary information and, as a result, learn from the game (Kim et al. 2017).

However, there is a chance that engaging games will undermine the desired learning objectives. This became clear during Game 1 in the investigation. While playing the game, students had trouble connecting the game's content to the objectives of the lesson and recognizing the fundamentals of infrastructure management, despite the fact that it was tough and entertaining for them. Due to this, the game's median SDI score was low, and Game 7 was used as the course's first exercise instead (Hartmann A. and Gommer L., 2021). A high median SDI score and substantial variations in non-self-determined motivation compared to Game 1 were seen in Game 7 due to the more direct way in which the relevant infrastructure management issues were addressed and the attraction of the game. The fact that students could easily integrate Game 7 into the overall course material and utilize the game to study removed non-self-determined incentive. Important elements of the learning through games experience include having a grasp of the subject matter and how the games relate to the course material (Hartmann A. and Gommer L., 2021). The purpose of a game in a course can be explained to students through tutorials, introductory lessons, and exam rounds.

The examples under investigation also demonstrate that factors such as the length of time allotted for game play, the game's functioning, and the quantity and clarity of game instructions can negatively affect students' motivation. But game playability has no real impact on pupils' motivation (Papanastasiou G. P., Drigas A.S. and Skianis C., 2017). Only for demotivation is there a minor but substantial direct influence, which can result from inactive periods, failing to use macros, and having too many players on the team, as seen in Games 3, 5, and 6 (Hartmann A. and Gommer L., 2021). The value of game operativeness for motivation therefore rests in its side effects, such as game attractiveness and learning. It offers the justification for maintaining the appeal of games as a requirement for learning. Some games' functional shortcomings and temporal constraints lessen their allure. Since of unplanned breaks or interruptions, students no longer felt completely involved in the lesson, and many thought the game was too tough because they couldn't follow the directions or complete the objectives (Hartmann A. and Gommer L., 2021). At the end, they realized they had not learned anything from the game. In order to use the motivating benefits of game attractiveness and learning, a teacher must first take precautions against any potential operational game inadequacies (Frank A., 2007).

5. Conclusion

Concluding, we emphasize the significance of all digital technologies in the field of education and especially in engineering training, which is highly effective and productive and facilitates and improves assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere [53-62], various ICTs applications that are the main supporters of education [63-98], and AI, STEM, and ROBOTICS that raise educational procedures to new performance levers [99-117] and games which transforms the education in a very enjoyable and friendly procedure [118-126]. Additionally, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the cultivation of emotional intelligence [127-172], as well as with environmental factors and nutrition [49-52], accelerates and improves more than educational practices and results, especially in sustainable engineering education.

The Covid-19 pandemic-restricted environment is likely to transform how education is carried out, which is predicted to increase interest in digital game-based learning (DGBL). Realistic worlds may now be created and developed for video games thanks to technological breakthroughs. Simulator games for augmented reality (AR) and virtual reality (VR) are also being created and used more and more for instruction and training. In the context of engineering, games (desktop, VR, and AR) have the potential to be utilized to convey difficult-to-imagine concepts, molecular activity, and risky or expensive situations that would have been otherwise hard to access for classroom usage. It is anticipated that practitioners will find games to be appealing as a pedagogical tool in the end due to their potential. The usage of digital games for engineering education is likely to increase even more with better technology and internet connections available to students.

According to academic experts, including instructional computer games and simulations in engineering courses may boost the effectiveness of teaching, inspire students, and make courses more entertaining. In addition, while using simulations and games in their lectures, professors express their worries regarding classroom management and the potential for gaming addiction. According to the data examined regarding the use of computer-based educational games in engineering instruction, incorporating games into engineering instruction may enhance the caliber of engineering instruction, inspire students, and enable the industry to gain well-educated engineering students, in accordance with the views of the engineering staffs. The academic staff of the engineering faculty generally supports the usage of educational video games in their classes. Nonetheless, there is a demand for games that are suitable for engineering curricula. Hence, initiatives to create instructional video games and computer simulations should be supported by policy makers in order to encourage faculty members to employ them in engineering education.

The research leads us to the conclusion that educational games, like any other teaching instrument used in engineering, support the coexistence of many motivating forms. The interaction between game attractiveness, game learning, and game operativeness can help to explain this coexistence. The ability to play the game becomes a prerequisite for educational games to realize its challenge and engagement potential, which will in turn frame students' learning experiences. This investigation has implications for game design in engineering education, including how to incorporate different game mechanics to satisfy human needs at their core and boost motivational potential. The fact that game mechanisms should always be viewed in connection to the educational environment in which they are employed is another corollary of this.

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