Serious Games in Higher Education in Education 4.0

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The digital transformation associated with the Fourth Industrial Revolution is having an impact on the way we teach. Under the term Education 4.0, new teaching methods, new technologies, as well as a student-centered approach, are expected to be used in teaching. One established method of teaching is the use of Serious Games, as it has various positive effects in terms of motivation and engagement.

serious games | systematized review | higher education | Education 4.0

1. Introduction

Education, like other areas of our society, is subject to social change. In the 18th century, Education 1.0 developed alongside the First Industrial Revolution, with the lecturer at the center and learners assuming a predominantly passive role [1]. The second industrial revolution was succeeded by Education 2.0, which also centered on the lecturer, albeit with learners assuming a more active role [1]. This was succeeded by Education 3.0, which was characterized by computerization. Teachers were no longer at the forefront, but instead curated courses that empowered learners to educate themselves independently [1]. In recent years, the renewed transformation of industry has brought about a further changes in education, encapsulated by the term *Education 4.0* [1]. This transformation is characterized by technological advancements enabling digitalization, virtualization, datafication, and smartification [2]. It entails a shift from teacher-centered to student-centered teaching and from passive to active learning [3].

The term Education 4.0 is defined differently depending on the perspective. Based on the new industrial revolution to Industry 4.0, Education 4.0 should provide resources to develop skills for this [4]. Miranda et al. [1] see other components in addition to this, such as the integration of new teaching methods as well as the implementation of current and new information and communication technologies as well as the use of new infrastructure to improve learning processes. They and other authors see the term in connection with new teaching–learning methods of active learning and innovative pedagogical procedures [1][2].

Challenges thus appear in the context of higher education with regard to new technologies, large amounts of data, and innovations in teaching and its secure infrastructure [5][6]. Furthermore, changes in the structure of higher education appear to be emerging. In the future, students will determine for themselves the content they wish to experience, and when and how. This shift leads to the development of new curricula and methods such as the *Flipped Classroom* or collaborative project work [7][8].

Considering that Abt [9] defined the term *Serious Games* as early as 1971, it can be assumed that the utilization of Serious Games in university teaching precedes the era of digitalization and Education 4.0. Although the term *Education 4.0* was coined in 2015, the scientific literature only increasingly refers to it from 2018 onward [10]. Nevertheless, it can be inferred that the introduction of new teaching methods influences the utilization and design of already existing methods. One such method is the use of Serious Games. Abt [9] conceptualizes Serious Games as a fusion of serious thinking and problem-solving with the experimental and emotional freedom of gaming [9]. Chen and Michel define Serious Games as games whose main purpose is not entertainment, fun, or pleasure [11]. In education, they can prompt students to engage with content for longer durations compared to other teaching formats and can have a motivating effect on them [12][13][14]. Backlund and Hendrix [15] also report mostly positive effects on problem-solving skills, learning impact, and motivation to learn.

A concept that has been addressing the digitalization and technical equipment of universities for some time is that of the *Pervasive University*. This concept pertains to the development of a personalized technical infrastructure that remains partially unnoticed by the user, thereby avoiding technical barriers and disruptions [16]. For this reason, the concept seems to share certain similarities with the field of Education 4.0, particularly in focus on the user and integration of new technologies into the university environment. Lucke et al. [17] have already considered the use of Serious Games in this context and cite a few examples. However, these examples do not fully incorporate the possibilities of the Pervasive University or Education 4.0 but instead concentrate on the user's location.

2. Serious Game Objective

The focus of 15 of these games is to teach knowledge. This knowledge is located in the areas of computer science (n = 6), medicine (n = 4), pharmacy (n = 1), the environment (n = 1), engineering (n = 1), logistics (n = 1), and mathematics (n = 1). It is noteworthy that in the fields of the environment and pharmacy, the same game is presented in two articles each. It is noticeable that the focus of the work is not always on achieving the objective of the game, i.e., imparting knowledge. For example, Antoniou et al. [18] use their game to impart medical knowledge, to evaluate physiological parameters, and to explore emotions during learning using virtual reality. The work aims to provide feedback based on the emotional state. The other games in this area have the purpose of motivating or engaging students [19][20][21][22][23][24], or increasing the learning effect [20][24][25][26][27][28][29][30][31][32][33].

The game from the field of pharmacy and the one from the field of logistics, in addition to the goal of imparting knowledge, also pursue the goal of enhancing teamwork [23][29][32]. The game presented by Ammouriova et al. requires solving challenges in teams and thus calls for leadership and task management skills [29]. In the case of the game for pharmacy students, a real pharmacy is simulated. Supported by team-building activities and coaching, students should learn to work together and communicate in an interdisciplinary way [23][32]. A game that focuses on teamwork is presented by Wong et al. Here, too, interprofessional collaboration is to be promoted with the help of a simulation [34].

The remaining six games, which do not aim to teach knowledge, are aimed at teaching other soft skills. One game has the goal of teaching engineering students how to solve design and manufacturing problems in virtual reality,

since this is a skills gap of undergratude students [35]. Conversely, the game FLIGBY is designed to teach entrepreneurs a leadership style that enables employees to work in an optimal mental state. Therefore, the students work in interdisciplinary teams and have to solve conflicts and communicate [36]. Teaching non-technical skills is the focus of the remaining games. Deniozou et al. [37] aim to teach students to take better notes. The game Compete! is about making decisions that improve one's soft skills like creative problem solving, stress management, and communication, as well as teamwork [38]. Two games impart knowledge about SCRUM, a procedure that structures the development of software in teams. Steghöfer and Burden [39] focus on teaching the necessary knowledge and skills, while Gordillo et al. [40] use and compare different methods for teaching.

3. Implementation

The majority of the games (n = 8) use simulations to achieve the game goal. Two of these games additionally use points [23][32][34]. Points are awarded in seven other games, but never without using an additional game element [19][21][27][28][30][37][40]. Similarly, the element of challenge is mostly used in combination with other elements [27][28][29][30][31][36][37][38][41]. Only in one of the nine games, the one from the logistics area, are challenges exclusively used as an element [29]. Five of the games employ puzzles [19][26][37][38][41], three use surprising or random elements [21][25][30], two use ranks [19][38], and two character advancement [21][38]. One game uses rewards and hidden content [31]. Another applies badges [19]. In one of the games, players are manually evaluated by lecturers [38]. The game GidgetML is characterized by using artifical intelligence to adapt the game content to the player [41].

Mini-games within the game are used in three games [31][38][40]. One game is designed as a quiz [20], another as a story-driven adventure [31], one as a strategic board game [21], and one in the IT security domain as a tower defense game [25].

Most articles do not explain why a mechanic was chosen but focus on the presentation of the game or the rules. Often rewards are understood as state-of-the-art and used because they fit the concept of the game. Espinha Gasiba et al. [27] explain that the decision to use a competitive design was made because this approach had led to higher motivation and engagement in previous studies.

The implementation of the games is realized differently. The majority of the games are realized as a desktop computer game (n = 7) or online or web app (n = 9). Apart from games outside a specific subject area, desktop games are mostly used in the field of medicine [21][22][31][37], while online/web app games are often used in computer science [20][25][26][27][39]. Two games describe a setup where teams work with computers but the game takes place in presence [23][32][42]. The game in the field of pharmacy especially stands out because actors are used for the simulation and only realistic software is used for the activities in the pharmacy [23][32]. Augmented, mixed, or virtual reality is used by four games in the area of computer science [19][40], medicine [18], and engineering [35]. More than half of the games (n = 15) are designed for single players, eight for multiple players. Most of the articles describe cooperative games in which players have to work together in teams. The game The Island from the field of environmental awareness and the game from the field of pharmacy have a competitive character with competing teams [23][32][33]. The game from the field of computer science with a focus on IT security was planned

as a singleplayer game, but has developed into a cooperative multiplayer game through agreements between players [27]. The game for learning anatomy is the only one that turns out to be exclusively competitive [21].

4. Evaluation

Various evaluation methods and study objectives are reported in the publications. Both Peña Miguel et al. and Saitua-Iribar et al. investigate whether the use of the Serious Game on environmental awareness impacts on different competencies of the players [24][33]. Peña Miguel et al. conclude that the game can promote competencies such as anticipation, systematic thinking, problem-solving, and critical thinking [33]. Saitua-Iribar et al. note that the game influences the knowledge level but not perceived meaningfulness [24]. Perrin et al. also report that students find the SUPER HEMO game helpful in acquiring knowledge. Furthermore, they report that the use of multimedia and mini-games has a positive impact on game enjoyment [31]. Similarly, students who tried a data-driven IT game reported an increase in knowledge in various areas of IT security [25]. In the same subject area, a game with challenges was reported as an adequate means of imparting knowledge [27]. However, it should be mentioned that all studies were conducted without a control group and were partially based on students' self-assessment. A study with a control group among students of a programming course shows that an adaptive game can have positive effects on motivation and continuous performance [41].

Fens et al. [32] examine how a non-digitally designed Serious Game can be integrated into the lecture curriculum using the example of a pharmacy course. The authors find that the game was offered by the majority of universities as a stand-alone mandatory course. Students are usually assessed in teams and as individuals. Depending on the exact learning objectives of the universities, varying amounts of capacity were used to deliver the game [32]. They investigated how students evaluate courses in which Serious Games are used and a positive evaluation was found [23][32]. Regardless of the course, other studies also found positive evaluations towards the use of Serious Games. In this context, students consider the learning effect through the game to be given and perceive an increase in motivation [19]. However, the expectations of Serious Games seem to depend on the game experience of the students, as shown by the results of Cook-Chennault et al. [28].

Regarding motivation, Buijs-Spanjers et al. [22] addressed whether and why students choose to intentionally make a decision within the game with negative consequences for the simulation. Reasons for the decision were, besides a different game experience, the interest in the simulation results based on their decision [22].

Games whose serious goal is to teach skills are considered by the authors to be helpful in terms of the game goal. An online Serious Game is described by Steghöfer and Burden as an effective teaching method for the SCRUM method [39]. The same is true for the game to improve the ability to take good notes [37]. FLIGBY enabled self-assessment and training of students' management skills [36].

Using virtual and augmented reality in the field of Serious Games is described as positive for the learning goal. Advantages are described with regard to various learning processes in the fields of medicine and computer science. In both studies, however, the interplay between the learning experience and students' emotions is pointed

out [18][19]. When comparing a virtual reality game with another game-based method, Gordillo et al. demonstrated that students with the virtual reality game were able to achieve the same level of knowledge of SCRUM as the comparison group, despite having a lower level of knowledge before the intervention.

5. Summary

The results reveal a heterogeneous landscape of Serious Games in university teaching. On the one hand, the areas of application and objectives vary, while on the other hand, the articles present markedly different concepts. This diversity is especially apparent in the mechanics utilized. The findings indicate that game designs often align with the serious objectives while the playful aspects are typically crafted at the developers' discretion, ensuring consistency in the game rules. In some instances, games were modeled after existing non-Serious Games, such as Minetest [39]. Customization of games can facilitate goal achievement, highlighting the advantage of developing Serious Games in interdisciplinary teams [43][44][45]. Furthermore, the articles demonstrate positive outcomes in their respective studies. Notably, the observed increases in motivation, learning effects, and the transfer of new knowledge or soft skills are consistent with previous research [15][46]. Insights from evaluations employing varied questions should inform the future design of Serious Games, particularly regarding the integration of multimedia and consideration of students' emotional states. These aspects are pertinent within the context of Education 4.0 [1][2][5][47].

References

1. Miranda, J.; Navarrete, C.; Noguez, J.; Molina-Espinosa, J.M.; Ramírez-Montoya, M.S.; Navarro-Tuch, S.A.; Bustamante-Bello, M.R.; Rosas-Fernández, J.B.; Molina, A. The Core Components of Education 4.0 in Higher Education: Three Case Studies in Engineering Education. Comput. Electr. Eng. 2021, 93, 107278.
2. 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.
3. Tang, S.; Long, M.; Tong, F.; Wang, Z.; Zhang, H.; Sutton-Jones, K.L. A Comparative Study of Problem-Based Learning and Traditional Approaches in College English Classrooms: Analyzing Pedagogical Behaviors Via Classroom Observation. Behav. Sci. 2020, 10, 105.
4. Mourtzis, D.; Vlachou, E.; Dimitrakopoulos, G.; Zogopoulos, V. Cyber- Physical Systems and Education 4.0—The Teaching Factory 4.0 Concept. Procedia Manuf. 2018, 23, 129–134.
5. Bonfield, C.A.; Salter, M.; Longmuir, A.; Benson, M.; Adachi, C. Transformation or evolution?: Education 4.0, teaching and learning in the digital age. High. Educ. Pedagog. 2020, 5, 223–246.

6. Jisc. Horizons Report—Emerging Technologies and the Mental Health Challenge—Jisc; Report of JISC, an UK Digital, Data and Technology Agency. 2019. Available online: https://repository.jisc.ac.uk/7284/1/horizons-report-spring-2019.pdf (accessed on 8 December 2023).
7. Aziz Hussin, A. Education 4.0 Made Simple: Ideas For Teaching. Int. J. Educ. Lit. Stud. 2018, 6, 92.
8. Fisk, P. Education 4.0 … the Future of Learning Will Be Dramatically Different, in School and throughout Life. 2017. Available online: https://www.peterfisk.com/2017/01/future-education-young-everyone-taught-together/ (accessed on 6 December 2023).
9. Abt, C.C. Ernste Spiele: Lernen Durch Gespielte Wirklichkeit; Kiepenheuer & Witsch: Cologne, Germany, 1971.
10. Costan, E.; Gonzales, G.; Gonzales, R.; Enriquez, L.; Costan, F.; Suladay, D.; Atibing, N.; Aro, J.L.; Evangelista, S.; Maturan, F.; et al. Education 4.0 in Developing Economies: A Systematic Literature Review of Implementation Barriers and Future Research Agenda. Sustainability 2021, 13, 12763.
11. Michael, D.R.; Chen, S.L. Serious Games: Games That Educate, Train, and Inform; Thomson Course Technology: Boston, MA, USA, 2005.
12. Boeker, M.; Andel, P.; Vach, W.; Frankenschmidt, A. Game-Based E-Learning Is More Effective than a Conventional Instructional Method: A Randomized Controlled Trial with Third-Year Medical Students. PLoS ONE 2013, 8, e82328.
13. Faiella, F.; Ricciardi, M. Gamification and learning: A review of issues and research. J. e-Learn. Knowl. Soc. 2015, 11, 13–21.
14. Susi, T.; Johannesson, M.; Backlund, P. Serious Games—An Overview; Technical Report HS-IKI-TR-07-001; School of Humanities and Informatics University of Skövde: Skövde, Sweden, 2007; pp. 1–28.
15. Backlund, P.; Hendrix, M. Educational games—Are they worth the effort? A literature survey of the effectiveness of serious games. In Proceedings of the 2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), Pole, UK, 11–13 September 2013; pp. 1–8.
16. Tavangarian, D.; Lucke, U. Pervasive University—A Technical Perspective Die Pervasive University aus technischer Perspektive. IT Inf. Technol. 2009, 51, 6–13.
17. Lucke, U.; Rensing, C. A Survey on Pervasive Education. Pervasive Mob. Comput. 2014, 14, 3–16.

18. Antoniou, E.P.; Arfaras, G.; Pandria, N.; Athanasiou, A.; Ntakakis, G.; Babatsikos, E.; Nigdelis, V.; Bamidis, P. Biosensor Real-Time Affective Analytics in Virtual and Mixed Reality Medical Education Serious Games: Cohort Study. JMIR Serious Games 2020, 8, e17823.
19. Lampropoulos, G.; Keramopoulos, E.; Diamantaras, K.; Evangelidis, G. Integrating Augmented Reality, Gamification, and Serious Games in Computer Science Education. Educ. Sci. 2023, 13, 618.
20. Malaise, Y.; Signer, B. King's Scroll: An Educational Game to Practise Code Prediction. In Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 2, New York, NY, USA, 15–18 March 2023; p. 1367.
21. Tan, W.J.; Ng, B.K.; Mogali, R.S. An Exploratory Digital Board Game Approach to the Review and Reinforcement of Complex Medical Subjects Like Anatomical Education: Cross-sectional and Mixed Methods Study. JMIR Serious Games 2022, 10, e33282.
22. Buijs-Spanjers, R.K.; Hegge, H.H.; Cnossen, F.; Jaarsma, A.D.; de Rooij, E.S. Reasons to Engage in and Learning Experiences From Different Play Strategies in a Web-Based Serious Game on Delirium for Medical Students: Mixed Methods Design. JMIR Serious Games 2020, 8, e18479.
23. Fens, T.; Dantuma-Wering, C.M.; Taxis, K. The Pharmacy Game-GIMMICS® a Simulation Game for Competency-Based Education. Pharmacy 2020, 8, 198.
24. Saitua-Iribar, A.; Corral-Lage, J.; Peña-Miguel, N. Improving Knowledge about the Sustainable Development Goals through a Collaborative Learning Methodology and Serious Game. Sustainability 2020, 12, 6169.
25. Løvgren, D.E.H.; Li, J.; Oyetoyan, T.D. A data-driven security game to facilitate information security education. In Proceedings of the 41st International Conference on Software Engineering: Companion Proceedings, Montreal, QC, Canada, 25–31 May 2019; pp. 256–257.
26. Ünlü, K.; Ardıç, B.; Tüzün, E. CRSG: A serious game for teaching code review. In Proceedings of the 28th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering, New York, NY, USA, 8–13 November 2020; pp. 1561–1565.
27. Espinha Gasiba, T.; Iosif, A.C.; Suppan, S.; Lechner, U.; Pinto-Albuquerque, M. Reflections on Training Next-Gen Industry Workforce on Secure Software Development. In Proceedings of the 5th European Conference on Software Engineering Education, New York, NY, USA, 19–21 June 2023; ECSEE'23. pp. 1–10.
28. Cook-Chennault, K.; Villanueva Alarcón, I.; Jacob, G. Usefulness of Digital Serious Games in Engineering for Diverse Undergraduate Students. Educ. Sci. 2022, 12, 27.

29. Ammouriova, M.; Bertolini, M.; Castaneda, J.; Juan, A.A.; Neroni, M. A Heuristic-Based Simulation for an Education Process to Learn about Optimization Applications in Logistics and Transportation. Mathematics 2022, 10, 830.
30. González-Campos, J.S.; Arnedo-Moreno, J.; Sánchez-Navarro, J. GTCards: A Video Game for Learning Geometric Transformations: A cards-based video game for learning geometric transformations in higher education. In Proceedings of the Ninth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'21), New York, NY, USA, 26–29 October 2021; pp. 205–209.
31. Perrin, J.; Meeus, A.; Broseus, J.; Morieux, P.J.; Di Ceglie, V.; Gravoulet, J.; D'Aveni, M. A Serious Game About Hematology for Health Care Workers (SUPER HEMO): Development and Validation Study. JMIR Serious Games 2023, 11, e40350.
32. Fens, T.; Hope, D.L.; Crawshaw, S.; Tommelein, E.; Dantuma-Wering, C.; Verdel, B.M.; Trečiokienė, I.; Solanki, V.; van Puijenbroek, E.P.; Taxis, K. The International Pharmacy Game: A Comparison of Implementation in Seven Universities World-Wide. Pharmacy 2021, 9, 125.
33. Peña Miguel, N.; Corral Lage, J.; Mata Galindez, A. Assessment of the Development of Professional Skills in University Students: Sustainability and Serious Games. Sustainability 2020, 12, 1014.
34. Wong, Y.H.J.; Ko, J.; Nam, S.; Kwok, T.; Lam, S.; Cheuk, J.; Chan, M.; Lam, V.; Wong, C.G.T.; Ng, H.Z.L.; et al. Virtual ER, a Serious Game for Interprofessional Education to Enhance Teamwork in Medical and Nursing Undergraduates: Development and Evaluation Study. JMIR Serious Games 2022, 10, e35269.
35. Zhao, R.; Aqlan, F.; Elliott, L.J.; Lum, H.C. Developing a virtual reality game for manufacturing education. In Proceedings of the 14th International Conference on the Foundations of Digital Games, New York, NY, USA, 26–30 August 2019; pp. 1–4.
36. Buzady, Z.; Almeida, F. FLIGBY—A Serious Game Tool to Enhance Motivation and Competencies in Entrepreneurship. Informatics 2019, 6, 27.
37. Deniozou, T.; Dima, M.; Cox, C. Designing a Game to Help Higher Education Students Develop Their Note-Taking Skills. In Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI), New York, NY, USA, 2–4 November 2020; pp. 181–192.
38. McGowan, N.; López-Serrano, A.; Burgos, D. Serious Games and Soft Skills in Higher Education: A Case Study of the Design of Compete! Electronics 2023, 12, 1432.
39. Steghöfer, J.P.; Burden, H. One block on top of the other: Using minetest to teach Scrum. In Proceedings of the ACM/IEEE 44th International Conference on Software Engineering: Software Engineering Education and Training, New York, NY, USA, 21–29 May 2022; pp. 176–186.

40. Gordillo, A.; López-Fernández, D.; Mayor, J. Examining and Comparing the Effectiveness of Virtual Reality Serious Games and LEGO Serious Play for Learning Scrum. Appl. Sci. 2024, 14, 830.
41. Miljanovic, M.A.; Bradbury, J.S. GidgetML: An adaptive serious game for enhancing first year programming labs. In Proceedings of the ACM/IEEE 42nd International Conference on Software Engineering: Software Engineering Education and Training, New York, NY, USA, 27 June–19 July 2020; pp. 184–192.
42. Baalsrud Hauge, J.; Söbke, H.; Bröker, T.; Lim, T.; Luccini, M.A.; Kornevs, M.; Meijer, S. Current Competencies of Game Facilitators and Their Potential Optimization in Higher Education: Multimethod Study. JMIR Serious Games 2021, 9, e25481.
43. Rooney, P.; O'Rourke, K.C.; Burke, G.; MacNamee, B.; Igbrude, C. Cross-Disciplinary Approaches for Developing Serious Games in Higher Education. In Proceedings of the Games and Virtual Worlds for Serious Applications, Coventry, UK, 23–24 March 2009; pp. 161–165.
44. Bellotti, F.; Berta, R.; Gloria, A.D. Designing Effective Serious Games: Opportunities and Challenges for Research. Int. J. Emerg. Technol. Learn. (iJET) 2010, 5, 22–35.
45. Souza, J.G.R.D.; Prates, R.O.; Santos, H.A. End-User Game Development Environments for Educators: Analyzing Platforms. In Proceedings of the 22nd Brazilian Symposium on Games and Digital Entertainment, New York, NY, USA, 6–9 November 2024; pp. 134–142.
46. Wouters, P.; Nimwegen, C.; Oostendorp, H.; Spek, E. A Meta-Analysis of the Cognitive and Motivational Effects of Serious Games. J. Educ. Psychol. 2013, 105, 249.
47. Hariharasudan, A.; Kot, S. A Scoping Review on Digital English and Education 4.0 for Industry 4.0. Soc. Sci. 2018, 7, 227.