**Supplementary Material 1:**

**Included Studies**

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| **Author and Year** | **Objective** | **Findings** | **Conclusion & Future Research** |
| Abdirahma et al. (2023) | To investigate gamification’s impact on self-directed learning in programming education. |

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| Gamification significantly improved SDL levels, from a mean of 3.52 to 4.63 after implementation. |

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 | Future studies could explore gamification in other subjects or broader educational contexts. |
| Aljabali et al. (2020) | Examine the effects of personalized gamification based on learning styles on student engagement and performance. | Personalized gamified learning significantly improves learning outcomes and perceived usefulness of the application. | Further research could investigate other gamification elements and their impact on diverse learning styles. |
| Altaie & Jawawi (2021) | To create an adaptive gamification framework to promote computational thinking (CT) for ages 8-13 based on learning preferences. | Gamification improves motivation and performance in CT, encouraging students to retake tests and enhancing engagement. | Further studies could test this framework across other age groups and examine other learning style models. |
| Bai et al. (2022) | Test a gamification model incorporating fantasy to improve online learning engagement | Addition of fantasy elements improved student engagement and peer interaction | Future research could investigate further motivational elements and assess their impact in varied educational contexts |
| Bennis et al., (2022) | To use ILS for generating adaptive learning games tailored to learning styles. | ILS integration led to tailored game generation, improving engagement by aligning with learner preferences. | Further development of tools like E-ILS for real-time adaptation could benefit adaptive learning game design. |
| Bhalerao et al. (2021) | To design gamification tools that help teenagers choose education paths based on personality traits. | Effective in identifying career paths through gamified personality assessment. | Research could expand to validate these tools in different educational or cultural settings. |
| Botte et al. (2020) | Analyze the correlation between gamification achievements and SDT in game-based learning. | Gamification achievements aligned with SDT fostered motivation by meeting basic psychological needs. | Further studies could examine the long-term effects of SDT-aligned achievements in diverse learning platforms. |
| Botte et al., (2022) | Explore the combination of Self-Determination Theory (SDT) principles and machine learning for adaptive reward systems in gamified learning. | Adaptive reward systems based on SDT improved motivational outcomes by catering to individual user needs. | Further research could focus on expanding machine learning techniques for more personalized and dynamic adaptation of rewards in gamification. |
| Chukwu (2024) | To examine the effectiveness of gamification in online learning. | Gamification enhances engagement, motivation, and learning outcomes when aligned with course objectives | Future studies should refine gamification strategies for diverse learners and evolving educational needs. |
| Doumanis et al. (2019) | Evaluate the impact of a multimodal collaborative virtual environment on learning | Multimodal CVEs significantly improved student learning outcomes and immersive experience | Future research could merge multimodal and traditional systems to maximize learning impact in collaborative environments |
| Dumas Reyssier et al. (2023) | Investigate adaptive gamification’s impact on different motivation types over time in secondary education. | Adaptive gamification influenced different motivation types variably; adaptation was most effective after five lessons. | Future research might explore which specific game elements consistently enhance intrinsic motivation. |
| El-Bishouty et al. (2019) | To assess course support for various learning styles using FSLSM in LMS design. | Courses designed with FSLSM show improved student learning aligned with learning styles. | Future work should focus on scaling the course analyzer tool for diverse learning environments. |
| Farikah et al., (2023) | Explore how e-learning tools enhance student engagement through SDT in online team-based learning. | Engagement was driven by competence, autonomy, and relatedness, which are core aspects of SDT. | Future research could explore additional SDT-based strategies to improve student engagement in virtual learning. |
| Fatahi (2019) | To evaluate adaptive e-learning systems based on personality and emotion models. | Adaptive environments enhanced learning rates, with students showing more engagement and personalized response. | Expanding adaptation to other personality and emotion models could provide deeper insights into user engagement. |
| Hallifax et al. (2019) | Identify factors for effective tailored gamification designs that match user types. | Motivation varies by game element and activity domain; Hexad is effective for tailored gamification. | Further studies are suggested to generalize findings across different activities and user typologies. |
| Hao & Tasir (2024) | Create a theoretical framework for integrating MOOCs with gamification to boost higher-order thinking skills (HOTS) | Gamified MOOCs enhanced HOTS development and engagement in online courses | Future research could explore which gamification elements most effectively engage students in MOOCs for HOTS enhancement |
| Hasan et al. (2019) | Investigate a gamified collaborative environment in Moodle to boost engagement | Gamification led to increased engagement and motivation in collaborative online discussions | Future work could adapt this approach to other LMSs and explore long-term effects on learning outcomes |
| He et al. (2024) | To design gamified teaching for improving motivation and achievement in IT education. | Gamification increased student motivation and improved achievement compared to traditional methods | Further research might examine gamification in different curricula and its scalability in higher education. |
| Ilbeigi et al. (2024) | To foster critical thinking in construction engineering education using gamified pedagogy. | Gamified pedagogy helped students grasp fundamental concepts effectively through active exploration. | Future research could adopt this interactive approach in other engineering or technical fields. |
| Jeong (2019) | To assess the role of online collaborative learning in enhancing motivation and engagement. | Collaborative learning activities positively affect motivation, engagement, and metacognitive benefits. | Future research could apply similar methodologies in different language and education levels. |
| Kang & Kusuma (2020) | Assess the effectiveness of a personality-based gamification model for foreign vocabulary learning. | The Hybrid Learning Model improved learning achievements and motivation, showing a positive correlation between motivation and academic performance. | Future research could examine the model's effectiveness across other languages and age groups. |
| Kian et al. (2022) | To analyze intrinsic motivation-driven game elements for a gamified learning platform. | Positive impact of game elements like group quests on student motivation, especially in collaborative settings. |  |
| Lavoué et al. (2019) | To adapt gaming features in learning environments based on player types to enhance engagement. | Adaptive gaming features significantly increase engagement for motivated learners and reduce amotivation. | Future research could explore more specific adaptation mechanisms for diverse learner profiles to optimize engagement. |
| Leclercq et al. (2020) | Investigate the effects of perceived justice in gamification within online communities. | High distributive justice can decrease enjoyment in gamification, particularly for low-engaged members. | Further studies could examine justice perception’s role in other digital learning environments to avoid negative impacts. |
| Liu & Lu (2021) | Focusing on the Collaborative Educational Gamification Authoring System (CeGAS), are multifaceted and center on empowering teachers to create effective game-based learning experiences | The results showed that 83% of students found the educational games to be fun. 87% of students expressed willingness to use the learning system. | Integrating the Unity 3D game engine and network database technology to create an interactive and collaborative 3D game editor based on the 5E learning cycle and facilitating easier sharing of teaching plans and learning resources. |
| Lopez & Tucker (2021) | Assess how adaptive and counter-adaptive gamification impacts individual performance based on player type. | Adapted gamified applications improved performance, while counter-adaptive applications reduced it. | Future work could optimize adaptive gamification strategies for specific player types to maximize positive performance outcomes. |
| Mohamad et al. (2019) | To implement adaptive learning with gamification to improve engagement for TVET students. | Enhanced learning engagement and critical thinking among students, validated through awards and real projects. | Future research might explore other educational contexts and refine gamification elements for broader applicability. |
| Nyembe & Howard (2019) | Assess learning theories' relevance to Mobile Collaborative Learning (MCL) using WhatsApp | Theories like collaborative learning and social learning theory were found beneficial for MCL | Future studies could apply these theories to other mobile platforms and evaluate their effectiveness in diverse educational contexts |
| Othman & Ching (2024) | To evaluate gamified science education using board games for young learners. | Computerized board games significantly improved academic performance and collaboration. |

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| Future work could refine game designs and assess their impact across varying age groups and subjects. |

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| Páez-Quinde et al. (2023) | Use gamification as a collaborative resource for technological education | Gamification improved engagement and motivation in technological learning contexts | Future studies might explore gamification across different technical subjects and educational contexts |
| Rodrigues et al. (2024) | Compare the impact of personalized gamification versus one-size-fits-all (OSFA) on motivation. | No significant differences in motivation across designs, but personalization benefits some demographics more. | Future work may explore multidimensional personalization approaches to improve motivation universally. |
| Rodríguez et al. (2021) | Propose an adaptive gamification approach that personalizes game elements based on dynamic player profiles. | Initial results indicate the adaptive approach enhances user experience when compared with randomized or fixed configurations. | Future studies should focus on refining dynamic adaptation and exploring its impact on long-term engagement. |
| Ros et al. (2020) | To analyze the impact of gamification on self-perception of success and effectiveness in cybersecurity | Realistic game design and contextualization significantly influenced perceived success and learning effectiveness | Future studies could explore gamification's dropout prediction and its scalability in various disciplines. |
| Rudolf (2022) | Assess gamification’s role in promoting collaborative learning in chemistry | Gamification enhanced collaborative skills and knowledge retention among students | Future research could implement this method in other STEM fields and examine cross-disciplinary impacts |
| Saçak & Kavun, (2020) | Investigate online collaborative learning theory’s application with Flipgrid and VoiceThread | Tools like Flipgrid fostered collaboration and engagement in online environments | Future research could expand to include additional digital tools and measure long-term impacts on learning outcomes |
| Scott & Campo (2023) | The study aimed to explore the use of an adaptive 3D virtual learning environment for training software developers in Scrum, by tailoring learning content according to the processing dimension of the Felder-Silverman learning style model. | Results showed that students in the adaptive group achieved **slightly higher learning gains** and **more consistent outcomes,** although the difference was **not statistically significant** (p = 0.780), likely due to a **small sample size**. The study involved 26 students, mostly male undergraduates, with a majority identified as **active learners.** | Future research should include **larger samples** for generalization, **application in professional settings,** and **variations in learner models, performance metrics, and teaching strategies.** The adaptive approach can also be extended to **other Agile methods.** Additionally, there is a need to assess the **reliability of the test instrument** and consider **tool adaptability and data security.** |
| Timonen & Ruokamo (2021) | Design a coaching pedagogy model for synchronous collaborative online learning | The coaching pedagogy model improved collaborative knowledge construction in webinars | Future research could explore the model’s application across different synchronous learning platforms |
| Torres et al. (2021) | Develop a gamified educational network to foster collaborative learning online | Preliminary evaluations showed high usability and satisfaction among users | Future studies could enhance collaborative features for wider applications in e-learning systems |
| Tramonti et al. (2021) | To explore the combination of gamification techniques and 3D virtual environments in v-learning to design innovative learning settings. | Demonstrated the potential of gamification combined with 3D virtual environments to foster innovative and student-centered learning. | Future research could focus on evaluating the long-term impacts of these approaches and exploring their scalability in broader educational contexts. |
| Velaora et al. (2022) | To enhance competency-based learning in digital design using gamification. | Gamified environments motivate students, boost creativity, and enhance higher-order cognitive skills. | Further research might explore long-term effects of gamification on learning competencies. |
| Xavier (2020) | To boost motivation in Portuguese language learners using a gamified, quest-based website. | Gamified activities using rewards effectively increased student motivation. | Research should explore gamification's potential in larger or more diverse learner groups. |
| Yusoff & Shafiril (2019) | To implement gamification in a VR game to motivate students and teach high-order thinking skills. | Serious games motivated learners and improved cognitive skills like analysis and creation. | Expanding this approach to other subjects and student demographics could yield broader insights. |
| Zaric et al. (2021) | Investigate the moderator role of learning tendencies on gamification success regarding academic participation, engagement, and experience. | Gamification positively contributes to academic participation and engagement, with students' learning tendencies moderating engagement. | Future studies could explore diverse gamification designs to enhance engagement in learners with different learning styles |