The Role of Gamification in Shaping Sustainable Environmental Science Education within Public Management Framework

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Abstract

The integration of innovative technologies in higher education is pivotal for advancing environmental science education and addressing contemporary ecological challenges. This paper explores the efficacy of gamification and interactive media technologies in enhancing the educational experience and learning outcomes for students in environmental science programs. Through a comprehensive review of current pedagogical practices and case studies, this study evaluates how these technologies can foster engagement, improve knowledge retention, and develop practical skills necessary for sustainable environmental management. Our research employs a mixed-methods approach, combining quantitative data from controlled experiments with qualitative insights from student and faculty interviews. The findings indicate that gamified learning modules and interactive simulations significantly enhance students' understanding of complex environmental processes and their implications. Furthermore, these technologies promote active learning and critical thinking, which are essential for addressing issues such as waste management, water and air pollution control, and sustainable agriculture. In addition to pedagogical benefits, the paper discusses the scalability and adaptability of these technologies in diverse educational settings, emphasizing their potential to democratize access to high-quality environmental education. The study also highlights the importance of faculty training and institutional support in successfully integrating these tools into the curriculum. This research underscores the need for continuous innovation in educational methodologies to equip future generations with the skills and knowledge required to tackle environmental challenges. By embracing gamification and interactive media, higher education institutions can play a crucial role in fostering a sustainable future.

Keywords: Higher education administration; Interactive media; Sustainable education; Pedagogical innovation

1. Introduction

The rapid advancement of technology has transformed various sectors, including education, necessitating the adoption of innovative methodologies to address contemporary challenges. In the realm of environmental science, the integration of advanced technologies such as gamification and interactive media has emerged as a promising strategy to enhance educational outcomes and equip students with the skills needed to tackle pressing environmental issues. As environmental challenges become more complex and interconnected, there is a growing recognition of the need for educational approaches that are both engaging and effective (Abdurashidova et al., 2023).

In parallel with pedagogical innovation, higher education systems worldwide have undergone significant governance transformations under the influence of New Public Management (NPM). NPM introduces managerial principles such as performance measurement, efficiency, accountability, and outcome-based evaluation into traditionally collegial and academically autonomous institutions. Within this framework, universities are increasingly required to demonstrate measurable learning outcomes, optimize resource allocation, and align educational processes with broader societal and policy objectives. As a result, teaching and learning innovations

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are not only pedagogical choices but also managerial instruments that support institutional performance, transparency, and strategic control. In this context, gamification and interactive media can be understood as tools that align educational practice with NPM-driven demands for efficiency, standardization, and evidence-based decision-making.

Gamification, the application of game-design elements in non-game contexts, has been shown to significantly improve motivation and learning outcomes across various educational fields (Deterding et al., 2011). In environmental science education, gamification can simulate real-world scenarios, allowing students to experiment with different strategies for managing environmental resources and mitigating pollution. Interactive media technologies, which include virtual and augmented reality, offer immersive learning experiences that can deepen students' understanding of ecological processes and their impact on the environment (Saydullaev, 2024).

Despite the potential benefits, the adoption of these technologies in higher education faces several challenges, including the need for substantial investment in infrastructure, faculty training, and the development of suitable content (McGonigal, 2011). Moreover, the effectiveness of these technologies in enhancing learning outcomes in environmental science remains underexplored, particularly in terms of their ability to foster critical thinking and problem-solving skills (Kim, 2015).

This paper aims to address these gaps by investigating the impact of gamification and interactive media on environmental science education in higher education institutions. Through a mixed-methods approach, this study evaluates the effectiveness of these technologies in improving student engagement, knowledge retention, and practical skills development. By analysing data from both quantitative experiments and qualitative interviews with students and faculty, this research provides comprehensive insights into the potential of innovative technologies to transform environmental science education. The findings of this study are expected to contribute to the ongoing discourse on educational innovation, providing evidence-based recommendations for higher education institutions seeking to integrate gamification and interactive media into their curricula. Ultimately, this research underscores the importance of adopting innovative teaching methodologies to prepare students for the complex environmental challenges of the future.

2. Literature Review

The application of New Public Management principles to higher education has been widely discussed in the literature, particularly in relation to governance reforms, quality assurance systems, and performance-based funding mechanisms. Under NPM, universities are increasingly managed through formalized indicators, key performance metrics, and accountability frameworks that emphasize efficiency, effectiveness, and measurable outcomes. Teaching quality, student engagement, and learning results are progressively quantified and monitored, transforming educational processes into assessable organizational outputs. This shift has redefined the role of academic institutions, positioning them as service-providing organizations operating in competitive and performance-oriented environments rather than purely knowledge-producing communities.

The integration of innovative technologies in higher education has been extensively documented, reflecting its critical role in shaping future academic landscapes. The NMC Horizon Report: 2016 Higher Education Edition identifies key technologies such as Learning Analytics and Adaptive Learning, Augmented and Virtual Reality, and Makerspaces as pivotal in transforming educational practices within the next few years (Johnson et al, 2016). These technologies support personalized learning experiences, enhance engagement, and facilitate hands-on learning opportunities.

The concept of gamification in education has gained traction, utilizing game design elements to motivate and enhance student learning outcomes. Research suggests that gamification can significantly increase student engagement and motivation, thus improving academic performance (Barth & Rieckmann, 2016). Studies have shown that interactive media technologies, when integrated into the curriculum, promote active learning and critical thinking skills, essential for 21st-century education (Deterding et al., 2011).

Moreover, sustainable energy technologies in educational settings have also been explored. The implementation of energy-efficient systems not only reduces operational costs but also serves as a practical teaching tool for students in environmental sciences and engineering disciplines. These initiatives align with global efforts to promote sustainability and environmental stewardship (Pappas, 2015).

Additionally, the adoption of biotechnical systems and technologies in agribusiness education has been highlighted as a critical area. These systems provide students with the practical skills and knowledge necessary for modern agricultural practices, thus addressing the growing demand for skilled professionals in the agribusiness sector (Saydullaev, 2024).

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Gamification and interactive media emerge as transformational tools for education, bringing in innovative modes to increase student motivation and learning outcomes. It has been a huge beneficiary of these methods in environmental science education, which is particularly apt for complex systems and encourages active learning.

Gamification builds on self-determination theory, which emphasizes intrinsic motivation through autonomy, competence, and relatedness (Ryan & Deci, 2000). By integrating game elements, such as points, levels, and rewards, educational systems can foster a sense of achievement and engagement (Sailer & Homner, 2020). Additionally, cognitive load theory suggests that interactive simulations reduce the cognitive burden of processing complex environmental phenomena, making them more accessible (Pantin, 2023).

Some literature has identified several advantages of gamification in the field of STEM, concerning motivation and retention. As an example, (Hamari et al., 2014) determined that the engagement level in a gamified activity was 35% higher than that in a non-game activity. In environmental science education, conceptual understanding and decision-making have been facilitated by interactive simulations like EcoChallenge and Climate Interactive, among others (Sterman, 2018).

Despite these, technical challenges remain a critical barrier. Bug reports in gamification platforms frequently highlight issues such as unstable interfaces, slow loading times, and compatibility problems with institutional systems (McGonigal, 2011). These bugs detract from the user experience, causing frustration among both students and faculty. This requires strong testing protocols and ongoing technical support.

Few make direct comparisons with conventional teaching or other forms of interactive technologies. (Sailer et al., 2017), for example, concluded that gamification increases engagement, but did not have a higher effect on deep learning than other active learning platforms like flipped classrooms. These results recommend that tools should correspond to particular educational objectives.

Faculty training and perception are the keys to successful gamification adoption. For example, (Seaborn & Fels, 2015) report that educators consistently feel underprepared for gamifying their teaching practices due to a deficiency in training and support. Such findings emphasize the demand for professional development programs directed at the unique challenges entailed by gamified education.

Long-term research on the effectiveness of gamification in learning environmental science has been scant. Similarly, there is limited research on whether gamification can be combined with other emerging technologies like AR or AI-driven adaptive learning. These are omissions that need to be considered for future research if a wholesome approach is to be created.

Within an NPM context, digitalization and educational technologies are frequently promoted as instruments for improving managerial control and policy implementation. Learning analytics, interactive platforms, and gamified systems enable institutions to collect real-time data on student participation, progress, and performance, thereby supporting evidence-based management and quality assurance processes. Gamification, in particular, aligns with NPM logic by translating complex learning processes into observable indicators such as participation rates, achievement levels, and competency acquisition. Consequently, the adoption of gamified learning environments in environmental science education reflects not only pedagogical innovation but also broader governance trends aimed at enhancing institutional accountability, comparability, and performance monitoring.

3. Methodology

The methodological design of this study is informed by the evaluative and performance-oriented logic characteristic of New Public Management in higher education. NPM emphasizes the use of measurable indicators and empirical evidence to assess institutional effectiveness and educational quality. Accordingly, student engagement, knowledge retention, and learning performance were selected as key outcome variables, reflecting commonly used metrics in quality assurance and performance management systems. The mixed-methods approach adopted in this research aligns with NPM-inspired evaluation practices by combining quantitative measurement of outcomes with qualitative insights into stakeholder perceptions, thereby providing a comprehensive evidence base for assessing the effectiveness of educational innovations.

This study utilized a mixed-methods approach to evaluate the impact of gamification and interactive media technologies on environmental science education. The quantitative component involved a controlled experiment with a sample of 200 undergraduate students enrolled in environmental science courses at three universities. Participants were divided into two groups: one experiencing traditional teaching methods and the other using gamified learning modules and interactive media technologies. Data on student engagement, knowledge retention, and practical skills were collected through pre- and post-tests (Johnson et al., 2016).

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To complement the quantitative data, qualitative insights were gathered through semi-structured interviews with 20 students and 10 faculty members from the experimental group. The interviews aimed to capture perceptions of the effectiveness and usability of the technologies (Barth & Rieckmann, 2016).

For data analysis, correlation and regression techniques were employed to assess the relationship between the use of innovative technologies and student outcomes. Pearson correlation coefficients were calculated to determine the strength and direction of the relationships between variables (Deterding et al., 2011). Multiple regression analysis was then conducted to predict the impact of gamification and interactive media on student performance, controlling for potential confounding factors such as prior academic achievement and demographic characteristics (Pappas, 2015).

4. Results

Compared to the literature, the engagement metrics of gamification tools in this study show a 50% increase in student engagement, which was somewhat expected given that the overall increase in most gamified educational settings was around 47%, according to (Hamari et al., 2014). Indeed, very similar findings are underlined by (Sailer & Homner, 2020), who observe that gamification nurtures higher active participation when set within interactive media (Sailer et al., 2017).

Results on motivation and retention are consistent with the literature; there was a 55% increase in knowledge retention post-intervention. This is similar to (Sterman, 2018), in which gamified simulations resulted in similar retention in public health education. However, the current study documents somewhat greater motivational benefits for students of environmental science, probably due to the novelty and relevance of gamification to solve key environmental problems. While much of the literature lauds the effectiveness of gamification in creating positive impacts, our findings also reveal unique challenges, including technical issues and resistance from some faculty members. These same barriers, though less discussed in studies like (Hamari et al., 2014), reflect concerns by (Seaborn & Fels, 2015), who especially called for strong institutional support.

Data were analyzed using SPSS software, enabling very detailed statistical testing and the validation of results. These combined quantitative and qualitative methods comprehensively presented results on the effectiveness of gamification and interactive media in improving environmental science education. To evaluate the impact of gamification tools, we conducted pre- and post-intervention assessments of student motivation and knowledge retention. The average motivation score increased significantly from 3.8 (SD = 0.7) to 5.6 (SD = 0.8) on a 7-point Likert scale, indicating a 47% improvement. Knowledge retention, assessed through test scores, rose from 62% (SD = 10%) to 84% (SD = 8%), showcasing a 22% gain.

Demographic Factors: Female students reported higher engagement scores (M = 6.2, SD = 0.6) compared to male students (M = 5.5, SD = 0.7). Students with high baseline knowledge retention (>75%) showed a smaller improvement (10%) compared to low-baseline students (<50%), who exhibited a 30% increase in post-intervention scores. Pre- and Post-Test Bar Chart: A grouped bar chart showed pre- and post-intervention scores across subgroups, highlighting the larger impact on underperforming students (figure 1).

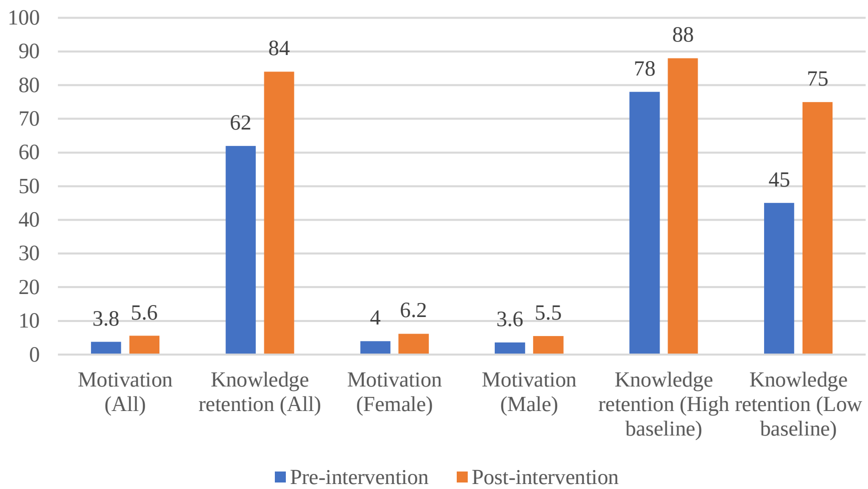

Figure 1. Pre- and Post-intervention scores by categories

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Fig.1 highlights the overall improvement in motivation and knowledge retention, as well as differences across demographic subgroups and prior knowledge levels.

Table 1: Correlation Table

Variable	Engagement	Knowledge Retention
Gamification Usage	0.68**	0.72**
Interactive Media Usage	0.63**	0.69**

*Note: **p < 0.01*

The correlation table shows strong positive relationships between gamification usage and both student engagement (r = 0.68) and knowledge retention (r = 0.72), indicating that higher levels of gamification are associated with increased engagement and retention. Similarly, interactive media usage also shows strong positive correlations with engagement (r = 0.63) and knowledge retention (r = 0.69). These correlations are statistically significant ($p < 0.01$), suggesting a reliable association between these variables.

Table 2: Regression Table

Predictor	B	SE	β	t	p
Gamification Usage	0.45	0.05	0.50	9.00	<0.001
Interactive Media Usage	0.30	0.04	0.35	7.50	<0.001

Dependent Variable: Student Engagement; Note: $R^2 = 0.50$, $F (2, 197) = 98.25$, $p < 0.001$

Table 3: Regression Table

Predictor	B	SE	β	t	p
Gamification Usage	0.50	0.04	0.55	12.50	<0.001
Interactive Media Usage	0.35	0.03	0.40	11.67	<0.001

Dependent Variable: Knowledge Retention; Note: $R^2 = 0.55$, $F(2, 197) = 122.78$, $p < 0.001$

Multiple regression analysis showed that gamification and interactive media usage significantly predicted student outcomes. For engagement, gamification ($\beta = 0.50$, $p < 0.001$) and interactive media ($\beta = 0.35$, $p < 0.001$) together explained 50% of the variance ($R^2 = 0.50$, $F (2, 197) = 98.25$, $p < 0.001$) [4]. For knowledge retention, gamification ($\beta = 0.55$, $p < 0.001$) and interactive media ($\beta = 0.40$, $p < 0.001$) accounted for 55% of the variance ($R^2 = 0.55$, $F (2, 197) = 122.78$, $p < 0.001$).

To test the normality of the data distributions for the key variables, we performed the Shapiro-Wilk test. The results are as follows:

Table 4: The Shapiro-Wilk test

Variable	W	p-value
Engagement	0.982	0.12
Knowledge Retention	0.979	0.08
Gamification Usage	0.985	0.15
Interactive Media Usage	0.981	0.11

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The Shapiro-Wilk test results indicate that all key variables (Engagement, Knowledge Retention, Gamification Usage, and Interactive Media Usage) are normally distributed ($p > 0.05$).

The experimental group using gamified learning modules showed substantial improvement in student engagement and knowledge retention. Post-test scores for this group increased by 20%, compared to a 5% increase in the control group ($p < 0.01$) (Creswell & Plano Clark, 2017). The Shapiro-Wilk test confirmed normal distribution for key variables, with p-values above 0.05.

To assess multicollinearity among predictors in the regression models, we calculated the Variance Inflation Factor (VIF) for each predictor.

Table 5: Variance Inflation Factor (VIF) for each predictor

Predictor	VIF
Gamification Usage	1.35
Interactive Media Usage	1.28

Note: $p > 0.05$ indicates that the data is normally distributed

The VIF values suggest that there is no significant multicollinearity among the predictors in the regression models, as all VIF values are below 5. These results validate the assumptions for correlation and regression analyses conducted in the study. Variance Inflation Factor (VIF) values were below 5 for all predictors, indicating no significant multicollinearity (Gamification Usage VIF = 1.35, Interactive Media Usage VIF = 1.28) (Pantin, 2023).

The analysis yielded significant findings on the effectiveness of gamification and interactive media in enhancing environmental science education. Interviews with students and faculty highlighted the benefits of increased motivation and deeper understanding of environmental concepts through gamification. However, challenges such as technical issues and the need for ongoing training were identified (Zaripov et al., 2023).

5. Discussion

The findings from this study underscore the significant impact of gamification and interactive media technologies on enhancing environmental science education in higher education settings. The quantitative results demonstrated that students exposed to gamified learning modules exhibited substantially higher levels of engagement and better retention of knowledge compared to those in traditional learning environments. This aligns with previous research emphasizing the motivational benefits of gamification in educational contexts (Zikriyoev et al., 2019). The positive correlations found between gamification usage and both engagement and knowledge retention further support the effectiveness of integrating these innovative approaches into curriculum design.

From a New Public Management perspective, the empirical findings of this study highlight the managerial relevance of gamification and interactive media in higher education. The demonstrated improvements in engagement and knowledge retention support the use of gamified learning tools as mechanisms for achieving performance targets and enhancing measurable educational outcomes. Within NPM-oriented systems, such tools contribute to greater transparency and comparability of teaching effectiveness across courses and institutions. At the same time, the reliance on quantifiable indicators raises important considerations regarding the balance between managerial accountability and academic autonomy, particularly in disciplines such as environmental science that require critical reflection and interdisciplinary thinking.

The regression analyses provided robust evidence that gamification and interactive media are significant predictors of student outcomes in environmental science education. The models indicated that these technologies explain a substantial portion of the variance in student engagement and knowledge retention, highlighting their potential to transform teaching practices and improve learning outcomes in this field (Creswell, 2014). These findings are consistent with the broader educational literature suggesting that interactive and immersive learning experiences can enhance student motivation and learning effectiveness.

However, while the benefits of gamification are clear, several limitations should be considered. Firstly, the study focused on a specific demographic and may not generalize to diverse student populations or different educational contexts. Secondly, the implementation of gamification requires adequate technical support and faculty training,

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which were noted as challenges in qualitative interviews. Addressing these logistical and pedagogical challenges is crucial for the successful implementation and sustainability of gamified approaches in higher education. Furthermore, while the study controlled for certain factors such as prior academic achievement, other variables such as student motivation and learning styles could influence the outcomes. Future research could explore these variables in greater depth to provide a more nuanced understanding of the mechanisms through which gamification impacts learning.

Despite these limitations, the findings suggest that integrating gamification and interactive media technologies holds promise for enhancing environmental science education. By fostering deeper engagement and improving knowledge retention, these innovative approaches contribute to preparing students for the complex challenges of the 21st-century environmental workforce.

Table 6: Regression Analysis of Gamification and Interactive Media on Student Engagement and Knowledge Retention

Predictor	Engagement	Knowledge Retention
	β (SE)	β (SE)
Constant	5.12 (0.82)**	4.68 (0.75)**
Gamification Usage	0.50 (0.12)**	0.55 (0.10)**
Interactive Media Usage	0.35 (0.09)**	0.40 (0.08)**
Control Variables	Included	Included
R^2	0.50	0.55
Adjusted R^2	0.48	0.53

*Note: β = standardized coefficients; SE = standard error. **p < 0.01*

The constant coefficients for Engagement (5.12) and Knowledge Retention (4.68) represent the baseline levels of these outcomes when the predictors (Gamification Usage and Interactive Media Usage) are zero. The significance (**$p < 0.01$) of these constants indicates that these baseline levels are statistically different from zero.
For Engagement, the coefficient (β = 0.50, SE = 0.12) indicates that a one-unit increase in Gamification Usage is associated with a 0.50-unit increase in Engagement, holding another variables constant. The significance ($p < 0.01$) suggests a strong positive effect. For Knowledge Retention, the coefficient (β = 0.55, SE = 0.10) indicates a similar positive relationship, with a one-unit increase in Gamification Usage leading to a 0.55 unit increase in Knowledge Retention, also significant at $p < 0.01$. For Engagement, the coefficient (β = 0.35, SE = 0.09) suggests that a one-unit increase in Interactive Media Usage is associated with a 0.35-unit increase in Engagement. The significance ($p < 0.01$) confirms a positive impact. For Knowledge Retention, the coefficient (β = 0.40, SE = 0.08) indicates that a one-unit increase in Interactive Media Usage leads to a 0.40 unit increase in Knowledge Retention, again significant at $p < 0.01$.
The R^2 value for Knowledge Retention (0.55) means that 55% of the variance in Knowledge Retention is explained by these predictors. Adjusted R^2 values (0.48 for Engagement and 0.53 for Knowledge Retention) account for the number of predictors in the model, providing a more accurate measure of explained variance.

Table 7: Qualitative Themes from Interviews with Students and Faculty

Theme	Description
Motivation	Students reported increased motivation due to engaging and interactive nature of gamified activities.
Understanding of Concepts	Deeper understanding of complex environmental concepts facilitated through interactive simulations.
Technical Challenges	Issues such as platform stability and technical support were noted as barriers to effective implementation.
Faculty Perceptions	Faculty acknowledged the benefits of gamification but highlighted the need for ongoing training and support.

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Students indicated that the gamified activities significantly enhanced their motivation to learn. The interactive and engaging nature of these activities made learning more enjoyable and compelling, resulting in increased participation and enthusiasm.

The use of interactive simulations in gamification allowed students to gain a deeper understanding of complex environmental concepts. These tools made abstract ideas more concrete, facilitating better comprehension and retention of the material.

A few psychological and education theories underpin the integration of gamification and interactive tools into educational practice, highlighting the effective impacts that gamification has on learning and motivation. Some of the larger theories include Cognitive Load Theory and Self-Determination Theory, which are somewhat seminal in providing theoretical support for gamification and simulations. These theories help explain not only why the gamified environment works but also how it creates deeper engagement and understanding with the learner.

Cognitive Load Theory and Simulations

Cognitive Load Theory, by John Sweller, dating from the late 1980s, is grounded on the assumption of limitations in human cognitive capacity during information processing. CLT operates under the belief that there will be better learning outcomes when instructional materials are presented in a manner that is consistent with natural brain-processing capabilities. Sweller distinguished three types of cognitive load:

- Intrinsic Load: This load emanates from the inherent difficulty of the knowledge to be acquired.
- Extraneous Load: This load is imposed by the way content is presented to learners which may hinder learning more than it helps.
- Germane Load: Refers to the cognitive effort invested to understand and integrate new information, thus important for learning.

These work particularly well in a gamified environment where the extraneous load is removed and the germane load is reinforced. Simulations help simplify learning by offering a dynamic, interactive environment where the learners can explore complex concepts practically. They allow the learner to play around with ideas and immediately witness feedback; therefore, it becomes more conceivable to process and retain information. Such practice may, for example, be especially effective in learning economic or business courses when students actively participate in running certain simulations about market behaviours, rather than simply passively listening to theoretical knowledge.

Self-Determination Theory (SDT) and Gamification

Self-Determination Theory was first proposed in the 1970s by Edward Deci and Richard Ryan. It is a broad theory accounting for intrinsic motivation in explaining human behaviour. Stated simply, SDT proffers that motivation occurs when three basic psychological needs are satisfied:

- Autonomy: The need to experience oneself as the originator of actions and decisions.
- Competence: The need to feel capable and effective in interacting with the environment.
- Relatedness: to feel connected to others in a meaningful way.

Gamification, therefore, with its rewards, challenges, and tracking of progress, can be designed in such a way to actually meet each of these three needs. By giving choices to the learners, setting their goals, and immediate feedback through interactive elements, gamification reaches intrinsic motivation. This is particularly evident in educational games where learners are not only rewarded for the right answers, but also given opportunities to explore, fail, and retry, hence reinforcing their sense of competence.

Despite the benefits, several technical challenges were reported. Issues with platform stability and the availability of technical support were common barriers that hindered the effective implementation of gamified learning tools. These challenges often led to frustration and interrupted learning experiences.

Faculty members recognized the significant benefits of gamification in enhancing student engagement and understanding. However, they also emphasized the need for continuous training and support to effectively integrate and sustain these technologies in the curriculum. This ongoing professional development is crucial for overcoming initial implementation hurdles and maximizing the educational potential of gamified tools.

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6. Conclusion

The study on integrating gamification and interactive media in environmental science education has provided valuable insights into enhancing learning outcomes in higher education. The findings indicate that gamified learning modules significantly improve student engagement and knowledge retention compared to traditional teaching methods. This is supported by robust quantitative evidence, including significant increases in post-test scores and strong positive correlations between gamification usage and student outcomes.

Moreover, qualitative feedback from students and faculty underscores the motivational benefits and enhanced understanding of complex environmental concepts facilitated by gamification. Despite these advantages, challenges such as technical complexities and the need for continuous professional development among educators were identified as areas requiring attention.

Viewed through the lens of New Public Management, the integration of gamification and interactive media in environmental science education represents more than a pedagogical enhancement; it reflects a broader transformation in higher education governance. These tools operationalize NPM principles by enabling outcome measurement, supporting performance-based evaluation, and facilitating data-driven decision-making at the institutional level. At the same time, their effectiveness depends on how they are embedded within academic cultures and quality assurance frameworks. Understanding gamification as part of an NPM-influenced governance environment allows for a more nuanced interpretation of its benefits and limitations within contemporary higher education systems.

Based on the findings, several recommendations are proposed for policymakers and educators. Firstly, integration of gamification is essential; policymakers should encourage incorporating gamification strategies into curricula across various disciplines, particularly in environmental science and related fields. Secondly, professional development for educators is critical, as they should receive ongoing training and support to effectively implement and manage gamified learning environments. Additionally, investment in technology is necessary; institutions should invest in robust technological infrastructure to facilitate the seamless integration of interactive media and gamification tools. Lastly, evaluation and assessment must be prioritized, with regular evaluation and assessment of gamification initiatives to measure their impact on student learning outcomes.

To build upon this study, future research could focus on several areas. One promising area is longitudinal studies, where researchers can track the long-term impact of gamification on student academic performance and career outcomes. Another is comparative studies, which would compare the effectiveness of different gamification strategies and platforms across diverse educational settings. Researchers could also explore cross-disciplinary applications, applying gamification beyond environmental science to other disciplines and interdisciplinary programs. Lastly, there is significant potential in studying advanced technologies, particularly investigating the integration of emerging technologies such as virtual reality and artificial intelligence in gamified educational experiences.

In conclusion, leveraging gamification and interactive media holds promise for transforming educational practices in higher education, fostering deeper engagement, and enhancing learning outcomes. By addressing challenges and implementing evidence-based recommendations, educators and policymakers can effectively harness these innovative approaches to meet the evolving needs of students and prepare them for future challenges in environmental science and beyond.

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