Exploring the Impact of Gen-AI-Enabled Gamification on Student Motivation, Engagement, and Learning Outcomes

Qiang Fu[1], Chuan-Peng Low[2,] Karen Loh[3]

Institute of Technical Education, Singapore[1, 2, 3]

Abstract

This study examines the impact of a Gen-AI-enabled gamification approach on student motivation, engagement, and learning outcomes in both theoretical and practical skills learning within Technical and Vocational Education and Training (TVET). Grounded in Self-Determination Theory (SDT), a four-month quasi-experimental study was conducted at the Institute of Technical Education (ITE), Singapore, involving 221 students. The study employed two parallel experimentations: one on business communication theory learning and another on practical life skills acquisition, with students divided into experimental and control groups. Findings reveal that students exposed to the Gen-AI-enabled gamified approach demonstrated significantly higher motivation and engagement in both theoretical and practical contexts. From a learning outcomes perspective, the experimental group outperformed the control group, achieving an 18.7% higher average score in practical skills tests (71.2 ± 18.7 vs. 60 ± 20, $p < 0.01$) and a 44.2% higher score in theoretical modules (62 ± 12 vs. 43 ± 11, $p < 0.01$).Critical analysis of the results highlights that AI-driven personalized learning and gamified incentives effectively sustain intrinsic motivation and adaptive engagement. While social gamification elements enhanced collaborative learning in both theoretical and practical contexts, their impact on relatedness was less pronounced, indicating opportunities for further refinement. Additionally, no significant differences were found across genders or learning styles, suggesting that the intervention benefits diverse learners equally. These findings underscore the potential of AI-powered gamification to enhance both conceptual understanding and hands-on skill acquisition, providing a scalable and adaptable pedagogical model for TVET education.

Keywords: *Generative AI, gamification, student motivation and engagement, learning outcome*

Introduction

The rapid advancement of digital technologies has significantly reshaped educational landscapes, necessitating innovative pedagogical strategies that cater to diverse learner needs. Among these, the integration of generative artificial intelligence (Gen-AI) and gamification has gained traction due to their potential to enhance student motivation, engagement, and learning outcomes (Deterding et al., 2011; Holmes et al., 2021). While both technologies have been individually explored in educational research, their synergistic integration remains underexamined, particularly in Technical and Vocational Education and Training (TVET) (Hamari et al., 2014; Zawacki-Richter et al., 2019). This study addresses this gap by investigating how Gen-AI-powered gamification can support TVET learning, which requires a balance of theoretical knowledge and hands-on skill acquisition.

Gamification, the use of game design elements in non-game educational contexts, has become a strategic tool to boost motivation, drive engagement, and promote active learning (Ryan & Deci, 2000; Hew et al., 2016). Techniques such as badges, leaderboards, and point systems provide real-time feedback and goal-oriented incentives, aligning closely with Self-Determination Theory (SDT) by satisfying learners' psychological needs for competence, autonomy, and relatedness (Deci & Ryan, 1985). While multiple studies affirm gamification's ability to support skill retention and learner persistence, critics caution against the potential erosion of intrinsic motivation when systems rely excessively on external rewards (Hamari et al., 2014).

Concurrently, Gen-AI technologies have broadened the landscape of adaptive and personalized learning, leveraging AI-powered content generation, real-time feedback, and intelligent tutoring to enhance student engagement and performance (Luckin et al., 2022). These AI-driven methodologies

enable dynamic, tailored learning pathways, fostering self-regulated learning and adaptive skill development. However, empirical research on Gen-AI in TVET remains limited, particularly concerning its synergistic integration with gamification to maximize both theoretical comprehension and hands-on proficiency.
This study, grounded in Self-Determination Theory (SDT), investigates the impact of Gen-AI-enabled gamification on motivation, engagement, and learning outcomes among TVET students. Specifically, it explores:

1. How Gen-AI-enabled gamification influences motivation and engagement in TVET learners;
2. The impact of AI-enhanced gamification on theoretical and practical learning outcomes;
3. The effectiveness of AI-powered gamification across different learning styles and demographic groups; and
4. Key success factors for integrating AI-enhanced gamification into TVET curricula.

By addressing these research questions, this study provides empirical insights into the pedagogical significance of AI-driven gamification and its role in transforming TVET education. It contributes to the broader discourse on digital innovation in education, presenting a scalable and adaptable framework for sustained engagement, enhanced skill acquisition, and continuous learning development.

Gamification in Education

Gamification, the use of game elements such as points, badges, and leaderboards in non-game contexts, has become a strategic pedagogical approach. It enhances intrinsic motivation by satisfying the psychological needs of competence, autonomy, and relatedness, as posited in Self-Determination Theory (SDT) (Ryan & Deci, 2000). Empirical research underscores gamification's role in improving learner persistence, collaboration, and achievement across diverse educational contexts (Landers, 2014; Sailer et al., 2017; Domínguez et al., 2013; Su & Cheng, 2015; Toda et al., 2019; Caponetto et al., 2014). However, sustained reliance on extrinsic motivators raises concerns about diminishing long-term engagement (Hamari et al., 2014; Seaborn & Fels, 2015; Mekler et al., 2017). Within vocational education, gamified approaches—especially those integrating simulations and authentic task environments—have shown measurable benefits in developing practical competencies and learner confidence (Al-Azawi et al., 2022; Dahalan et al., 2023; Elmashhara et al., 2023).

Gen-AI in Education

Generative AI technologies, such as ChatGPT and intelligent tutoring systems, offer real-time feedback, adaptive instruction, and personalized learning experiences that significantly reshape instructional design (Holmes et al., 2021; Luckin et al., 2022). These tools foster learner autonomy, metacognitive awareness, and cognitive engagement by dynamically tailoring content based on individual performance. A growing body of research demonstrates Gen-AI's capacity to cultivate higher-order thinking skills and adaptive learning pathways (Zawacki-Richter et al., 2019; Aleven et al., 2004; Kukulska-Hulme, 2020; Roll & Wylie, 2016; Chen et al., 2020; Wang et al., 2023). Nonetheless, scholars caution against ethical risks, including algorithmic bias, learner overdependence, and the opacity of AI decision-making processes, especially in domains requiring critical judgment and contextual awareness (Zhai et al., 2023; Binns, 2018; Holmes et al., 2021).

Integrating Gen-AI and Gamification in TVET

The integration of Gen-AI and gamification represents an emergent, high-potential domain within educational innovation, yet remains insufficiently explored in the context of vocational learning. Gamification promotes sustained learner engagement and goal-directed behavior, while Gen-AI offers adaptive scaffolding through intelligent feedback and real-time personalization (Gao, 2023; Lee & Hammer, 2011; Li et al., 2021; Kim et al., 2022; Cheng et al., 2023; Yang et al., 2021). Their convergence enables the development of dynamic, individualized learning environments that address both cognitive and psychomotor domains critical in TVET. Preliminary evidence from Luckin et al. (2022) and Spector (2020) indicates that AI-augmented gamified platforms can enhance motivation, retention, and skills transfer. However, the TVET sector continues to lack robust, large-scale empirical

studies evaluating implementation efficacy, learner variability, and institutional scalability (Zawacki-Richter et al., 2019; Al-Azawi et al., 2022; Elmashhara et al., 2023).

Theoretical Foundation: Self-Determination Theory (SDT)

To explain the motivational mechanisms underpinning the impact of Gen-AI and gamification, this study adopts **Self-Determination Theory (SDT)**. SDT posits that human motivation is driven by the fulfillment of three innate psychological needs: **competence**, **autonomy**, and **relatedness** (Ryan & Deci, 2000). Learning environments that support these needs are more likely to foster **intrinsic motivation**, which in turn leads to deeper engagement and improved learning outcomes.
Gamification aligns closely with SDT by providing learners with challenges that reinforce **competence**, choices that support **autonomy**, and interactive experiences that facilitate **relatedness** (Deci & Ryan, 1985; Sailer et al., 2017). For instance, mechanisms such as real-time feedback, point systems, and progression levels cater to learners' sense of efficacy and goal achievement. Simultaneously, Gen-AI amplifies these motivational drivers by enabling **adaptive learning**, where content and difficulty levels are adjusted in real time to match learners' individual progress. AI-generated feedback also allows for **personalized scaffolding**, reinforcing a learner's perception of competence and control. While SDT has been widely used to analyze gamification's impact in educational settings, its application to integrated AI-gamification environments remains limited. This study therefore extends SDT's utility by examining how the convergence of AI's adaptive capacity and gamification's motivational affordances collectively support learners in TVET contexts. In doing so, it provides a theoretical basis for designing pedagogical strategies that not only engage learners but also sustain their intrinsic drive toward mastering both theoretical knowledge and practical skills.

Research Gaps and Problem Statement

Despite growing interest in AI and gamification in education, key research gaps persist—especially within the context of **TVET**:

- **Lack of context-specific evidence**: Most empirical studies focus on general or higher education, leaving vocational education underrepresented (Al-Azawi et al., 2022).
- **Siloed treatment of AI and gamification**: Existing research often explores Gen-AI and gamification separately, overlooking the benefits of an integrated approach (Gao, 2023).
- **Limited understanding of learner variability**: Few studies investigate how learner differences—such as prior knowledge, learning styles, and demographics—interact with AI-enhanced gamified interventions (Koivisto & Hamari, 2019).

To address these gaps, this study investigates how the integration of **Gen-AI-enabled gamification** influences motivation, engagement, and learning outcomes among TVET students. Guided by **Self-Determination Theory**, it examines both conceptual and hands-on learning environments, while also evaluating its inclusivity across diverse learner profiles.

Methodology

This study employed a **quasi-experimental mixed-methods design** to evaluate the impact of Gen-AI-enabled gamification on motivation, engagement, and learning outcomes among TVET students in Singapore. Quantitative data provided objective measurement of performance and motivation, while qualitative insights enriched the interpretation of learners' experiences.

Participants

A total of 221 students from the Institute of Technical Education (ITE), Singapore, participated in the study. The sample comprised:

- **108 students** in the practical skills learning stream (life skills acquisition), with 57 in the experimental group and 51 in the control group.

- **113 students** in the theoretical module (business communication), with 71 in the experimental group and 42 in the control group.

Efforts were made to ensure diversity in gender, learning styles (including visual, auditory, and kinaesthetic) and prior academic backgrounds.

Instruments

- **Motivation and Engagement Surveys**: Adapted from validated SDT-aligned instruments to measure competence, autonomy, and relatedness.
- **Pre- and Post-Tests**: Subject-specific assessments measured theoretical understanding and practical skill acquisition.
- **Perception and Satisfaction Surveys**: Captured student attitudes toward Gen-AI and gamified elements.
- **Open-ended Feedback**: Qualitative responses captured insights on learner experience and engagement.

Procedure

Baseline Assessment: At the outset, both groups, studying theory and practical skills, completed a baseline survey and initial assessments to ensure comparability in terms of level of knowledge and skills as well as perception towards this study.
Intervention: Over a 16-week period, the experimental group participated in a Gen-AI-enabled gamified learning environment in either theory learning or practical skills acquisition. This included:

- AI-generated quizzes using classpoint, an AI-powered edutech software, tailored to individual learning needs.
- Gamified elements generated by classpoint such as leaderboards, points, and badges to incentivize participation.
- AI-powered content generation where teachers using ChatGPT to create content, e.g., scenario-based assignments, etc., and students are empowered to use gen-AI tools to work on assignments.
- AI-assisted tutor and marker where teachers uploaded teaching content, e.g., notes, mock paper, etc., to classpoint platform and students using AI-powered feedback tools to provide personalized or iterative guidance anytime and anywhere.

The control group, in both theory and practical learning experimentation, received traditional instruction, comprising lectures, assignments, manual feedback, group discussions, and scenario-based practice (for practical skills learning).
Post-intervention surveys and tests/assessment were administered to evaluate change in motivation, engagement, and learning outcomes as well as satisfaction level towards teaching and learning with (experiment group) or without (control group) pedagogical intervention as well. Open-ended responses and feedback from students to provide qualitative insights were also obtained.

Data Analysis

The treatment of dataset are as follows:

- **Quantitative data**: Descriptive statistics summarized overall trends. Paired t-tests and ANOVA were used to assess changes in motivation and performance.
- **Qualitative data**: Thematic analysis of open-ended responses and instructor observations provided context to support or contrast statistical findings.

This robust mixed-methods approach allowed triangulation of findings and a nuanced evaluation of how Gen-AI-enabled gamification influences motivation, engagement, and learning outcomes in diverse TVET learners.

Results

The analysis revealed that students exposed to Gen-AI-enabled gamification demonstrated significantly higher levels of **motivation**, **engagement**, and **learning performance** than those in the control group.

Motivation and Engagement

Survey data showed a marked increase in all three SDT dimensions—competence, autonomy, and relatedness—among experimental group participants:

- In practical modules, significant improvement was found across all dimensions (**$p < 0.01$**).
- In theoretical modules, improvements were moderate but statistically significant (**$p < 0.05$**), particularly for autonomy and engagement.

These results underscore the role of personalized AI feedback and gamified structures in sustaining learner motivation across contexts.

Learning Outcomes

The experimental group outperformed the control group in both theoretical and practical assessments:

- **Theoretical learning:** Experimental group scored an average of 62 ± 12, versus 43 ± 11 in the control group (44.2% higher, $p < 0.01$).
- **Practical skills**: Experimental group averaged 71.2 ± 18.7, compared to 60 ± 20 in the control group (18.7% higher, $p < 0.01$).

These gains reflect improved conceptual understanding and hands-on application attributed to the AI-enhanced gamified experience.

Learner Perception and Satisfaction

Both groups reported satisfaction with their learning experience; however, the experimental group highlighted specific benefits:

- Real-time feedback, adaptive difficulty, and interactive tasks were seen as major enhancers of learning.
- Students appreciated the autonomy to engage with content at their own pace.

Interestingly, no statistically significant difference was found in overall satisfaction levels, suggesting that intrinsic motivation may be equally fostered across modalities if aligned with SDT principles.

Impact Across Learning Styles and Demographics

No significant differences were observed in performance across gender, i.e., male and female, or learning styles, namely, visual, auditory, and kinaesthetic, indicating the inclusive potential of Gen-AI-enabled gamification. This supports the model's adaptability for diverse learner profiles in vocational education settings.

Qualitative Feedback

Student reflections reinforced the quantitative findings:

- Positive themes included increased motivation, improved focus, and enjoyment in learning.

- Challenges included occasional overreliance on AI tools and reduced peer interaction, highlighting areas for future refinement.

Overall, the results validate the efficacy of Gen-AI-enhanced gamification in promoting motivation, engagement, and improved learning outcomes in TVET contexts.

Discussion

The findings of this study underscore the evolving pedagogical paradigm wherein Gen-AI and gamification coalesce to redefine TVET learning environments. Far beyond addressing motivational deficits, this integration serves as a catalytic mechanism for reconfiguring how learners engage with content, peers, and self-regulated progression. By situating our results within the broader literature, this discussion highlights areas of both alignment and disruption, offering critical insights into the unique contributions of AI-enhanced gamified pedagogy in vocational education.

Amplifying Intrinsic Motivation through Adaptive Gamification

This study reaffirms that gamification can significantly elevate intrinsic motivation by supporting learners' psychological needs, as outlined in SDT (Ryan & Deci, 2000; Sailer et al., 2017). Yet, its true pedagogical potency emerges when combined with Gen-AI's adaptive capabilities. Unlike conventional static gamification, AI-powered systems dynamically calibrate difficulty, pacing, and task complexity—intensifying learners' sense of agency and competence. This reinforces findings by Roll and Wylie (2016) and aligns with Su and Cheng's (2015) proposition that adaptive challenges sustain engagement more effectively than uniform gamified designs.

What distinguishes this study is how learners perceived AI-generated feedback and gamified cues—not as extrinsic distractions but as integrated tools for meaningful progression. This nuanced response contradicts concerns raised by Hamari et al. (2014) that gamification might erode intrinsic drive through overreliance on rewards. Instead, the fusion of Gen-AI with gamified mechanisms reframes feedback loops as catalysts for self-determined learning. Learners used AI feedback to chart individualized learning trajectories, suggesting that when aligned with mastery-oriented design, gamification transcends tokenism and becomes an engine for authentic cognitive engagement.

The significant increase in motivation across all SDT constructs confirms prior research that gamification supports learner engagement by satisfying psychological needs (Sailer et al., 2017; Ryan & Deci, 2000). However, this study extends existing models by demonstrating that AI-enhanced gamification amplifies these motivational effects through personalized, real-time scaffolding. The ability of Gen-AI to adapt content difficulty dynamically enhances learners' sense of competence while offering autonomy in navigating their own learning pace—an effect corroborated by Roll and Wylie (2016) and further supported by the motivational architecture proposed by Su and Cheng (2015).

Contrary to the caution expressed by Hamari et al. (2014) regarding extrinsic overreliance in gamification, the present study suggests that when gamification is paired with AI-driven mastery-based progression, the risk of extrinsic motivational erosion diminishes. Learners viewed gamified AI feedback not as superficial incentives, but as functional tools aligned with task relevance and personal growth. This nuance underscores the evolution of gamification beyond surface-level mechanics toward intelligent, adaptive design.

Bridging Cognitive and Psychomotor Domains

These findings challenge the longstanding view that gamification yields greater benefits in procedural learning than in theoretical mastery (De-Marcos et al., 2017; Leaning, 2015). The observed 44.2% improvement in theoretical outcomes not only surpasses practical gains but also suggests that Gen-AI's adaptive scaffolding and context-aware scenarios play a critical role in cultivating deep conceptual understanding. This contradicts prior assumptions that gamified designs struggle with abstract knowledge transfer. Instead, the results illustrate how AI-personalized sequencing and real-time conceptual reinforcement can reduce cognitive overload and enhance retention, lending new empirical weight to Sweller's cognitive load theory (1988) in digitally mediated learning environments.

This aligns with Luckin et al. (2022), who emphasize AI's potential in facilitating situated learning. Furthermore, the improvement in practical outcomes reinforces the dual benefit of this approach in equipping TVET learners with both cognitive clarity and procedural fluency—core competencies for industry readiness.

Reframing Learner Satisfaction and Engagement

The distinction observed between learner satisfaction and actual engagement in this study is instructive. While both experimental and control groups reported positive satisfaction, only the experimental group demonstrated statistically significant gains in motivation and active engagement. This finding challenges the conventional assumption that satisfaction equates to engagement and instead supports a more nuanced interpretation—as suggested by Henrie et al. (2015)—that engagement is a multidimensional construct encompassing behavioral, emotional, and cognitive components.

The deeper engagement noted in the experimental group likely stemmed from AI's ability to generate a responsive, iterative learning experience. By enabling learners to control their pace while receiving real-time support, the Gen-AI-enhanced environment fostered sustained attention and personal relevance. This contrasts with earlier findings by Subhash and Cudney (2018), where gamified learning without AI support produced mixed engagement levels due to rigid content pathways and lack of personalization.

Furthermore, the persistence and immersion observed align with Fisher et al. (2013), reinforcing the idea that challenge-adaptive feedback and AI-driven content progression can serve as more powerful motivators than superficial reward systems. These outcomes point toward a paradigm shift in how learner engagement is conceptualized—not as a byproduct of enjoyment alone but as the product of dynamic, context-sensitive instructional design.

Although both experimental and control groups reported satisfaction, only the experimental group exhibited statistically significant improvements in motivation and engagement. This dissociation suggests that learner satisfaction may not be a direct proxy for engagement quality. The experimental group's deeper engagement likely stemmed from the iterative, self-paced learning loop facilitated by AI—challenging the findings of Subhash and Cudney (2018), who reported mixed outcomes in gamified environments without AI support.

Additionally, the high level of engagement observed in this study supports Fisher et al. (2013), who assert that gamification can increase persistence even in the absence of immediate satisfaction. In this case, AI-supported challenge adaptation and continuous feedback appear to provide a more enduring motivational architecture.

Inclusivity and Learner Diversity

The lack of significant performance differences across gender and learning styles highlights the inclusive affordances of Gen-AI-enabled gamification. In contrast to earlier critiques that gamified environments might favor competitive or extrinsically motivated learners (De-Marcos et al., 2017), this study suggests that AI-driven personalization mitigates such biases by adapting content delivery to individual learner profiles. This adaptive scaffolding appears to offer equitable learning pathways regardless of background, confirming assertions by Holmes et al. (2021) that intelligent systems can support broader learning access and equity.

Furthermore, these findings reinforce Kukulska-Hulme's (2020) critique of rigid learning style classifications. The success of a unified AI-gamified system across a heterogeneous learner base implies that real-time adaptability may supersede the need for predefined instructional tailoring. Rather than categorizing learners, Gen-AI identifies and responds to emergent patterns of need, offering a more fluid and inclusive framework for personalized instruction in vocational contexts.

The absence of significant differences in learning outcomes across gender and learning styles provides compelling evidence of the inclusive potential of Gen-AI-enabled gamification. This finding contradicts earlier concerns by De-Marcos et al. (2017) that gamification may privilege competitive or extrinsically driven learners. Instead, AI-driven personalization appears to neutralize these biases, supporting claims by Holmes et al. (2021) that adaptive systems can democratize learning opportunities.

Moreover, these results challenge traditional assumptions about learning style differentiation—visual, auditory, and kinaesthetic—often cited as key determinants of academic success in diverse

classrooms (Fleming & Baume, 2006). While past research has emphasized the importance of designing instruction tailored to individual learning styles, emerging evidence suggests that adaptive learning models powered by AI can accommodate diverse learners equally without requiring explicit differentiation (Holmes et al., 2021). This aligns with the argument that adaptive pedagogical strategies based on real-time feedback are more effective than static, learning-style-based approaches.

Theoretical Contributions and Practical Implications

Theoretically, this study extends the scope of Self-Determination Theory (SDT) by demonstrating how Gen-AI-enhanced gamification can operationalize psychological need satisfaction in a scalable, personalized manner. The integration of adaptive feedback and AI-calibrated challenge progression illustrates how competence and autonomy are dynamically reinforced, providing new empirical depth to SDT in digital learning environments. At the same time, the study highlights a theoretical limitation—namely, the underdevelopment of relatedness—which suggests that current Gen-AI platforms need further design considerations to support collaborative, socially rich experiences. This finding opens up a new avenue for SDT-informed research that integrates peer interaction within AI-enhanced frameworks.

From a practical standpoint, the study provides actionable insights for educators, instructional designers, and policy leaders. For practitioners, it offers a clear pedagogical model that blends gamified elements with Gen-AI to support differentiated learning across both theoretical and applied domains. The positive results across gender and learning style groups underline the inclusive design potential, especially within diverse TVET classrooms. For institutions, the findings support the strategic integration of Gen-AI-enabled gamification into curriculum design, student engagement systems, and formative assessment practices. Policymakers can also draw from this study to advocate for digital infrastructure investments that promote equitable, skill-based learning at scale. Moreover, the dual impact on cognitive development and hands-on skills reinforces the relevance of this model in advancing national workforce development goals, particularly in lifelong learning and upskilling initiatives.

Conclusion

This study sought to examine the impact of Gen-AI-enabled gamification on motivation, engagement, and learning outcomes in TVET education, guided by Self-Determination Theory. The findings reveal that integrating Gen-AI with gamification significantly enhances intrinsic motivation, fosters deeper learner engagement, and leads to measurable improvements in both conceptual understanding and practical performance. These outcomes validate the theoretical premise that SDT-aligned gamified environments, when augmented by AI, can optimize learning experiences by supporting psychological needs for competence, autonomy, and—though less strongly—relatedness.

The research contributes both theoretically and practically: it expands SDT's explanatory power in digital learning contexts and offers actionable insights for TVET institutions aiming to modernize pedagogy. In doing so, it positions Gen-AI-enabled gamification not as an isolated instructional enhancement, but as a holistic pedagogical model capable of driving equity, personalization, and skill integration at scale.

However, several limitations must be acknowledged. First, the study was conducted within a single institutional setting in Singapore, limiting the generalizability of findings across cultural or institutional contexts. Second, while short-term learning outcomes were captured, the long-term retention and transfer of knowledge were not assessed. Third, the lack of peer collaboration tools limited the exploration of social learning dynamics, particularly in relation to the SDT construct of relatedness.

Future research should address these limitations by conducting longitudinal and cross-contextual studies, exploring hybrid AI-human collaborative systems, and integrating peer-driven gamified elements to strengthen social engagement. Investigating the balance between automation and human facilitation will also be critical for designing emotionally intelligent and pedagogically sustainable AI-gamified ecosystems.

In summary, Gen-AI-enabled gamification emerges from this study not merely as an instructional trend, but as a transformative architecture for reimagining how TVET learners acquire knowledge, develop skills, and sustain motivation in the digital age.

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