Innovative Teaching and Learning
http://doi.org/10.4208/itl.20250202

7(2), 3-45
September 2025

Transforming Graduate Teaching Assistant Training Through Blended Learning, Gamification and AI: A Case Study

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Abstract

Graduate Teaching Assistants (GTAs) play an integral role in undergraduate education, yet many lack formal pedagogical training. This case study examines the implementation of an innovative, technology-enhanced GTA training program at a research-intensive university in Hong Kong. The program integrates blended learning, gamification, and artificial intelligence (AI) tools, guided by Self-Determination Theory (SDT), the Mechanics-Dynamics-Aesthetics (MDA) framework, and adult learning principles, to explore how an innovative pedagogical and technological design supports student engagement, fosters collaboration, and enhances self-perceived teaching confidence in mandatory professional development at scale.

Using a mixed-methods approach, data were collected from 449 students across six course sections during Fall 2024. Quantitative metrics showed high voluntary participation (97.6% of groups engaged in optional activities) and sustained engagement (81.7%), while qualitative insights from student reflections provided rich evidence of the integrated pedagogical design driving engagement. A custom gamification platform facilitated peer collaboration, sustained participation, and efficient resource management, while AI tools provided scalable pedagogical and administrative support, effectively addressing institutional constraints through innovative pedagogical strategies.

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The findings offer valuable insights for professional development practice, particularly in aligning engagement mechanisms with learning objectives in mandatory training contexts. While acknowledging the influence of institutional constraints and the limitations of short-term outcome measures, this case study demonstrates how well-designed technology solutions can support both scalability and personalization in professional development. Patterns of resource-sharing behaviors and collaborative practices further illustrate strategies for fostering community building while addressing the practical challenges of large-scale training programs.

Keywords: Graduate Teaching Assistant (GTA) training, professional development, gamification, blended learning, artificial intelligence in education, Self-Determination Theory, student engagement

Graduate Teaching Assistants (GTAs) play an essential role in undergraduate education, serving as grading assistants, tutorial facilitators, and lab demonstrators. Despite their crucial contributions, many GTAs lack formal training in pedagogy, student engagement, and classroom management, which can hinder their teaching effectiveness (DeChenne et al., 2012). To address this gap, universities provide professional development programs ranging from short workshops to semester-long courses (Saxena et al., 2022). However, these programs often face significant challenges, particularly in research-intensive institutions, where GTAs must balance teaching responsibilities with demanding academic priorities (Park & Ramos, 2002).

At the Hong Kong University of Science and Technology (HKUST), all full-time Research Postgraduate (RPg) students are required to undertake GTA responsibilities and complete a mandatory, zero-credit training program offered by the institute's central teaching support unit. While essential, this program is constrained by several persistent challenges: large-scale participation limits opportunities for personalized support, the diversity of disciplinary needs requires adaptable approaches, and the mandatory nature of the course often results in low motivation among participants. These challenges reflect broader issues in professional development programs, where rigid structures and limited resources undermine engagement and efficacy (Botham, 2018).

The importance of preparing GTAs extends beyond their immediate teaching roles. It represents a critical step in shaping the future professoriate (Gilmore et al., 2014). Addressing this dual purpose requires innovative approaches that not only enhance teaching readiness but also foster collaboration, motivation, and professional growth.

This paper examines an innovative approach to GTA training that addresses these challenges through three synergistic components: (1) blended learning that provides flexibility while maintaining structure, (2) gamification that transforms mandatory participation into engaged community building, and (3) AI support that scales personalized assistance across large cohorts. Guided by Self-Determination Theory (SDT), the Mechanics-Dynamics-Aesthetics (MDA) framework, and adult learning principles, this approach seeks to transform mandatory training into an engaging, scalable, and impactful learning experience. By aligning psychological and pedagogical needs with pedagogical and technological innovations, our approach supports the development of foundational teaching attitudes and

self-efficacy, enhances engagement, and fosters community building. Specifically, this study investigates the program's influence on student engagement, collaborative behaviors, and participants' self-perceived confidence in teaching competencies, as revealed through quantitative platform data and post-course survey responses

Using a mixed-methods case study, this paper examines the implementation of an innovative GTA training approach and its influence on key learning aspects in six parallel GTA training classes involving 449 students during Fall 2024. Drawing on quantitative engagement metrics and participants' self-reported teaching confidence levels and qualitative insights from student reflections, this study illustrates how carefully designed integration of pedagogy and technology can enhance student engagement, foster collaboration, and support self-perceived professional growth in mandatory training at scale. This case study offers practical insights for institutions facing similar challenges while contributing to a broader understanding of motivation and engagement in mandatory professional development contexts.

Theoretical Framework

Our innovative approach to transforming GTA training is informed by three complementary theoretical frameworks: Self-Determination Theory (Deci & Ryan, 1985) guides our understanding of motivation in mandatory professional development, the Mechanics-Dynamics-Aesthetics (MDA) Framework (Hunicke et al., 2004) informs our gamification design, and adult learning principles (Knowles, 1970) shape our implementation choices. Together, these frameworks provide a robust foundation for addressing the complexities of engagement, motivation, and learning in professional development contexts.

Motivation in Professional Development

Self-Determination Theory (SDT) provides a valuable framework for understanding and supporting motivation in mandatory professional development contexts. SDT posits that the quality of motivation depends on fulfilling three basic psychological needs: autonomy (sense of choice and volition), competence (sense of effectiveness), and relatedness (sense of connection) (Ryan & Deci, 2020).

Research in GTA development highlights persistent challenges: reduced engagement due to competing research priorities, diverse support needs across disciplines, and limited opportunities for meaningful peer interaction (Saxena et al., 2022). These challenges are particularly pronounced in mandatory programs, where

external requirements often diminish intrinsic motivation by restricting autonomy and reducing engagement (Deci & Ryan, 1985; Ryan & Deci, 2017). However, programs thoughtfully designed around SDT principles can address these challenges by fulfilling psychological needs, offering valuable insights for creating effective and engaging professional development for GTAs (Kajfez & Matusovich, 2017).

SDT's emphasis on nurturing basic psychological needs while maintaining structure is particularly relevant for addressing the complexities of GTA training. By designing programs that provide meaningful choices (autonomy), offer structured opportunities for skill development (competence), and foster peer connection (relatedness), institutions can transform mandatory requirements into opportunities for authentic professional growth (Ryan & Deci, 2020). These principles guide the development of interventions that enhance engagement while navigating the practical constraints of large-scale implementation.

Design Principles for Gamification

Gamification has demonstrated significant potential in higher education, with systematic reviews showing consistent benefits for student engagement, motivation, and enjoyment (Subhash & Cudney, 2018). However, while gamification's effectiveness is well-documented in various educational contexts, its application in GTA professional development remains unexplored, presenting an opportunity to address persistent engagement challenges in mandatory training programs.

The Mechanics-Dynamics-Aesthetics (MDA) Framework provides a systematic lens for analyzing and designing engaging gamified systems by considering three interconnected components: mechanics (rules and features), dynamics (run-time behavior), and aesthetics (emotional responses) (Hunicke et al., 2004). This framework guides thoughtful integration of gamification elements with learning objectives by ensuring alignment between system features and desired outcomes.

Recent research indicates that aligning gamification design with theoretical principles can enhance its ability to achieve intended outcomes, particularly in educational contexts (Gupta & Goyal, 2022). Beyond traditional point-based systems, reward redemption mechanisms can enhance engagement by providing meaningful choices that align with learners' goals (Gupta & Goyal, 2022). This is particularly relevant in higher education contexts, where adult learners prioritize rewards with clear practical benefits (Diefenbach & Müssig, 2019). Furthermore, experimental evidence suggests that such reward sys-

tems can enhance rather than undermine intrinsic motivation when they provide psychological meaningfulness to learning activities (Xiao & Hew, 2023).

From the mechanics perspective, MDA emphasizes how system rules and features create opportunities for meaningful interaction. In professional development contexts, this involves designing reward structures that support learning goals while providing clear value to participants. The framework's focus on dynamics helps predict how mechanics will generate patterns of behavior, particularly important when designing for collaboration and community building. The aesthetics component addresses the emotional experiences that emerge from interaction with the system, crucial for maintaining engagement in mandatory contexts.

Andragogical Principles in GTA Development

Knowles' Theory of Andragogy (1970) provides crucial insights for designing professional development that respects and leverages adult learners' characteristics. Three key assumptions particularly informed our design: adults' self-concept as autonomous decision-makers, the value of learners' experiences as resources for learning, and the interplay between external and internal motivation (Knowles, 1973; Knowles et al., 2005). These principles complement SDT by offering specific guidance for supporting autonomy and motivation in professional development contexts.

In GTA training, these assumptions suggest the importance of providing meaningful choices while leveraging participants' diverse expertise. Adults' self-concept as autonomous learners calls for flexible engagement pathways that allow them to make decisions about their learning journey. Similarly, the assumption of drawing on learners' experiences guided our approach to turn the limitation of having students from different disciplines to fostering community building, where GTAs can share and learn from diverse teaching perspectives (Bishop-Williams et al., 2017).

The assumption regarding motivation—that adults respond to both external and internal motivators—was particularly relevant for our mandatory training context. While Ryan and Deci (2020) note that external requirements can potentially undermine intrinsic motivation, thoughtfully designed reward systems can support both immediate engagement and deeper professional growth. This understanding informed our multi-tier and multi-component reward structure and resource-sharing mechanisms, which aim to transform external requirements into opportunities for meaningful development.

Artificial Intelligence in Supporting Professional Development at Scale

Alongside established learning theories, the integration of Artificial Intelligence (AI) in higher education offers transformative potential for supporting professional development, particularly in large-scale programs like GTA training, presenting promising solutions for enhancing teaching and learning at scale. AI-powered tools, such as chatbots, can provide scalable support, addressing diverse learner needs and logistical challenges inherent in extensive cohorts. Recent research highlights diverse applications of these tools in educational contexts, from providing pedagogical guidance to facilitating administrative processes (Labadze et al., 2023). Such tools can offer personalized learning experiences and are noted for their capacity to provide immediate assistance and access to information, which can significantly enhance learning experiences (Okonkwo & Ade-Ibijola, 2021) and support the development of competence through timely clarification and enhanced knowledge retention (Deng & Yu, 2023).

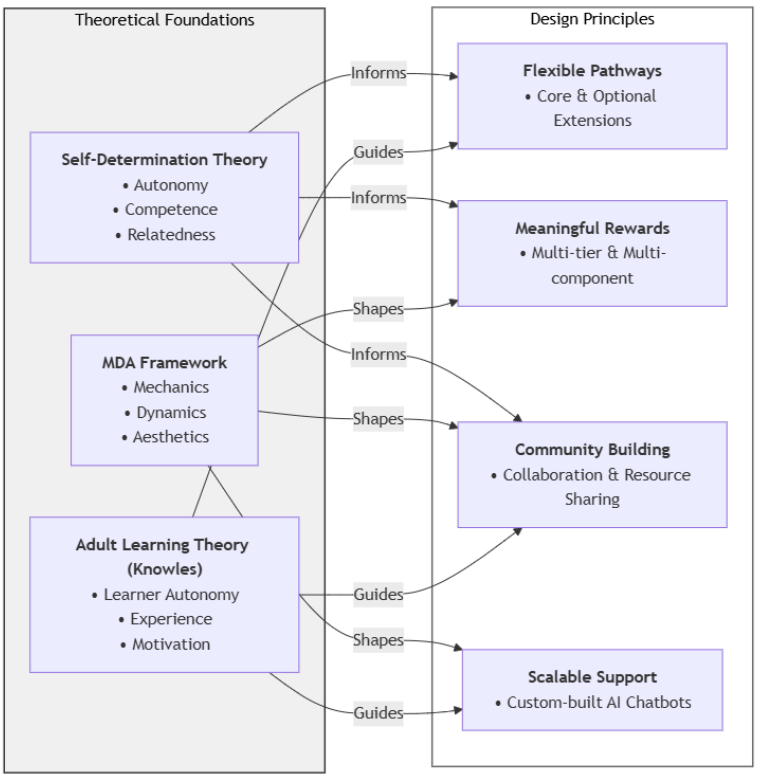
Furthermore, AI can function as a "force multiplier" for instructors (Mollick & Mollick, 2023), streamlining administrative tasks (Al Faruq et al. 2023; Crompton & Burke, 2023) and thereby freeing up valuable instructor time for more complex pedagogical interactions and individualized student guidance. In the context of GTA training, where chatbots have been explored as supplementary learning resources (Gonda & Chu, 2019), the inclusion of AI tools in our program not only aims to enhance the learning experience and provide efficient support but also serves to model innovative teaching practices, exposing future educators to the pedagogical applications of emerging technologies. The principled use of AI can thus complement frameworks like SDT by creating environments where learners receive consistent support for competence and can access information more autonomously, while also aligning with andragogical principles by offering accessible resources tailored to immediate needs. The specific AI tools developed for this program and their intended roles in operationalizing these benefits will be detailed in the Innovative Design Framework section.

The integration of these theoretical frameworks—SDT, MDA, and Andragogy—provides a comprehensive foundation for addressing the complexities of GTA training. SDT offers a lens to understand and address the psychological needs of participants, while MDA operationalizes these needs through carefully designed gamification mechanics, dynamics, and aesthetics. Andragogy complements these

frameworks by ensuring the program aligns with adult learners' preferences for autonomy, collaborative learning, and meaningful engagement. Together, these frameworks guide our approach to balancing structure with flexibility, supporting diverse learning needs, and fostering professional growth through meaningful engagement. This theoretical integration informs how we transform mandatory training into valuable professional development that supports both individual learning and community building. A visualization of this theoretical integration is presented in Figure 1.

Figure 1

Integration of Theoretical Frameworks and Design Principles



Note. This diagram illustrates how the foundational theories—Self-Determination Theory, MDA Framework, and Andragogy—inform and shape the core design principles of Flexible Pathways, Meaningful Rewards, Community Building, and Integrated Support.

Innovative Design Framework for GTA Training

Building upon these theoretical foundations, we developed an innovative approach to address the challenges of the university-wide GTA training program at HKUST. This mandatory program, serving over 800 full-time RPg students annually, faces significant challenges in delivering quality professional development across multiple large sections while addressing diverse disciplinary needs.

Our design framework translates the theoretical principles illustrated in Figure 1 into three interconnected implementation components: blended learning operationalizes flexible pathways, gamification realizes meaningful rewards and community building, and AI tools enable personalized support at scale.

While maintaining the program's core content and assessment structure, this framework transforms the delivery through careful alignment of theoretical principles with practical applications. The following sections detail how each component addresses specific challenges while fulfilling the psychological needs and learning preferences outlined in our theoretical framework.

Blended Learning: Core Content with Flexible Learning Opportunities

The blended learning design addresses GTAs' competing commitments by ensuring structured quality through face-to-face sessions while offering flexible opportunities for extended learning. The program organizes learning across three complementary phases: pre-class preparation, in-class active learning, and optional post-class challenges that allow participants to take ownership of their learning. This structure creates clear learning pathways while maintaining flexibility for students to engage based on their individual needs and interests.

Structured Pre-Class Preparation (Online)

Pre-class preparation introduces foundational pedagogical concepts and principles through interactive online materials. Each module equips GTAs with the baseline knowledge required for active participation in face-to-face sessions.

To ensure engagement and preparedness, compulsory module quizzes assess understanding and help GTAs identify areas for clarification. By addressing foundational concepts beforehand, this approach maximizes in-class time for interactive and collaborative activities.

Active In-Class Learning (Face-to-Face)

In-class sessions focus on applying theoretical concepts through discussions,

case studies, and group-based activities. These interactive experiences are designed to deepen participants' understanding of pedagogical principles and encourage active exploration of teaching strategies. The structured environment fosters collaborative learning while enabling participants to contextualize and connect theoretical knowledge to real-world teaching scenarios.

Optional Post-Class Challenges (Online)

Post-class challenges extend learning beyond core requirements through optional activities that encourage deeper engagement with pedagogical concepts. These challenges are designed to support autonomy by offering choices in engagement level while fostering competence through progressive skill development. Activities range from individual tasks to collaborative peer review, allowing GTAs to pursue areas of personal interest while building professional expertise. Integration with the gamification system connects these extension activities to the broader learning journey, motivating deeper engagement with pedagogical concepts.

Gamification: Driving Engagement, Personal Growth, and Collaboration

Transitioning from structured learning to sustained engagement presents unique challenges in professional development programs, particularly in large, diverse cohorts. Gamification offers a solution by transforming routine activities into interactive and rewarding experiences that enhance motivation, foster collaboration, and accommodate diverse learning preferences. Grounded in the Mechanics-Dynamics-Aesthetics (MDA) framework, our system integrates gamification elements to create a learner-centered environment where educational objectives and motivational design align seamlessly.

Key Design Features

Virtual Currency (mCoins). mCoins form the motivational backbone of the system, aligning with the mechanics of the MDA framework. Participants earn mCoins through individual and group tasks across pre-class preparation, in-class activities, and optional post-class challenges. By linking effort to tangible rewards, mCoins provide immediate feedback, fostering a sense of accomplishment and supporting competence as participants track their progress.

Multi-Tier and Multi-Component Reward Structure. Designed to operate at both individual and group levels, this multi-tier and multi-component reward system caters to diverse motivational drivers while maintaining alignment with learning objectives. It includes:

- Physical Collectibles: Thematic playing cards that evoke emotional engagement and novelty, supporting the aesthetics component by adding excitement and personalization to the experience.
- Digital Records: Trackable digital representations of achievements, reinforcing participants' sense of progress and accountability.
- Tangible Benefits: Practical rewards, such as selecting presentation slots, that provide meaningful incentives without impacting grades.

This innovative reward system connects participants' efforts with meaningful outcomes, fostering both personal growth and collaborative success.

Collaborative Mechanisms. Coin transfers and group challenges—the key dynamics elements—reinforce collaboration and shared responsibility. These mechanisms encourage resource sharing and teamwork, fostering relatedness and community building.

Custom Gamification Platform: The Hidden Tuck Shop

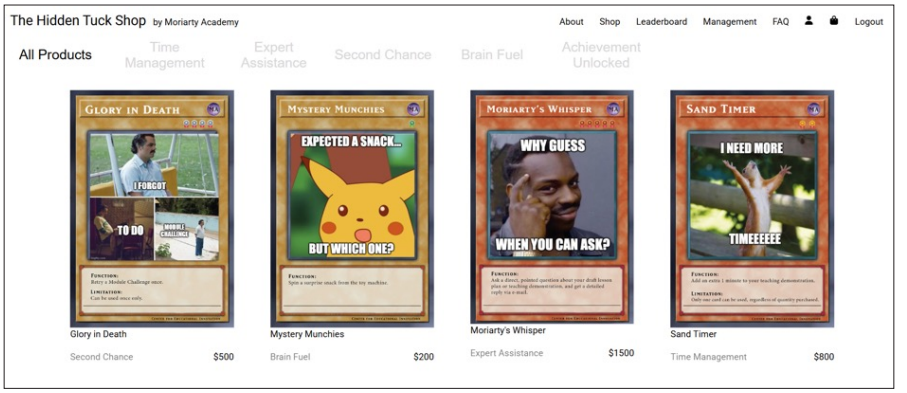
The Hidden Tuck Shop integrates the gamification system into a cohesive digital platform, balancing scalability with personalized engagement. Designed to align with the MDA framework, the platform incorporates structured mechanics (e.g., mCoins), emergent dynamics (e.g., collaborative resource sharing), and engaging aesthetics (e.g., thematic rewards) to create an interactive and emotionally rewarding experience.

The platform's core functionalities create a unified system for managing large-scale gamification. It tracks virtual currency earned by students, monitors engagement metrics, manages reward distribution, and facilitates resource sharing through coin transfers. By automating administrative tasks while preserving human interaction, the platform enables consistent quality and scalable gamification across all program sections. Figure 2 illustrates the platform's user interface, showcasing how the multi-tier and multi-component reward system is presented to students.

Individual rewards (shown in yellow) and group rewards (shown in orange) are presented as themed collectible cards with mCoin pricing. Each reward operates across multiple components: digital cards, physical collectibles, and tangible benefits. Categories include Time Management (e.g., "Sand Timer" for presentation scheduling), Expert Assistance (e.g., "Moriarty's Whisper" for instructor support), Second Chance (e.g., "Glory in Death" for assessment retakes), and Brain Fuel (e.g., "Mystery Munchies" for enjoyment rewards).

Figure 2

The Hidden Tuck Shop Interface



For students, the platform provides an intuitive interface modeled on familiar e-commerce experiences, minimizing cognitive load and enabling participants to track achievements, manage resources, and allocate mCoins toward personal and group rewards. This approach supports autonomy, fostering individual agency and collaborative decision-making.

For instructors, the platform streamlines program management through integration with Google Sheets. This allows efficient organization of student data, monitoring of engagement metrics, and oversight of reward distribution. By reducing administrative burdens, instructors can focus on facilitating collaboration and providing targeted feedback.

The platform exemplifies the aesthetics component of the MDA framework by creating a seamless, enjoyable experience for users while supporting the broader learning outcomes of collaboration, accountability, and competence.

AI Support: Scaling Personalized Support and Modeling Innovation

Delivering personalized support and encouraging deep engagement with pedagogical tasks in large-scale professional development programs, such as the GTA training at HKUST, presents considerable logistical and instructional challenges. Recognizing AI's potential for scalable, individualized assistance, our program integrates two custom-built AI chatbots. These tools are designed to complement instructional capacity, streamline logistical processes, and cultivate deeper pedagogical engagement

among GTAs. This strategic integration not only aims to enrich the overall learning experience but also serves to model innovative applications of AI within educational contexts.

The two custom-built AI chatbots, Mr. Watson and The Secretary, fulfill distinct yet complementary roles, contributing to a cohesive support system.

Pedagogical Support: Mr. Watson

Mr. Watson functions as a Socratic-style pedagogical assistant, designed to explain course content and clarify foundational concepts. Furthermore, when GTAs prepare for tasks such as lesson planning or teaching demonstrations, Mr. Watson guides them through associated challenges by employing reflective questioning rather than offering direct answers. This approach, which leverages AI's capacity for guided inquiry, reinforces critical thinking about pedagogical decisions and showcases AI's potential to deepen conceptual understanding, thereby enhancing the learning experience.

Administrative Support: The Secretary

The Secretary chatbot efficiently manages routine queries related to schedules, deadlines, and procedural details. By automating these operational tasks, The Secretary significantly reduces the administrative workload, allowing instructors to dedicate their expertise and time to more complex pedagogical interactions and direct student support.

Together, these tools enhance key aspects of the GTA learning environment. Students utilize Mr. Watson for pedagogical clarification and reflective dialogue, strengthening their instructional competencies. Meanwhile, The Secretary ensures smooth logistical support, preparing participants effectively for active engagement. By offering consistent, responsive, and scalable assistance across all program phases, these AI chatbots address the demands of large-scale professional development while exemplifying the innovative application of technology in education.

The three design components—blended learning, gamification, and AI support—work synergistically to address the core challenges of GTA training. Blended learning provides a structured framework that balances essential core content with opportunities for optional extensions, gamification drives sustained engagement through meaningful rewards and collaboration, and AI support extends personalized guidance at scale. Together, they create a comprehensive learning environment that balances educational quality with practical constraints while modeling innovative teaching practices.

Implementation

Program Structure

The Fall 2024 GTA training program spanned seven weeks, with Modules 1–4 delivered weekly during the first four weeks and Module 5 extending over the final three weeks. The program enrolled over 700 newly admitted full-time RPg students, distributed across 10 parallel sections. Each section, consisting of 72–78 students, was further divided into 12-13 collaborative groups to facilitate peer interaction and manageability. This structure promoted active learning while fostering a sense of community and shared responsibility among participants.

The program delivered its curriculum through five modules. Modules 1–4 focused on foundational pedagogical concepts, delivered through weekly 110-minute sessions combining pre-class preparation, in-class activities, and optional post-class challenges. Module 5 emphasized application through teaching demonstrations, where participants designed lesson plans and delivered mini-tutorials, receiving structured peer and instructor feedback.

To ensure consistency across sections, all learning materials, including multimedia content, quizzes, and challenge links, were hosted on the university's LMS. Interactive learning maps provided students with a visual guide to navigate their progress, while instructors used LMS dashboards to monitor student engagement and tailor their facilitation accordingly.

Learning Journey

Pre-Class Phase

The pre-class phase provided participants with a shared baseline of knowledge through interactive online modules hosted on the LMS. These modules included multimedia content, curated readings, and quizzes, visually organized within learning maps to guide participants through required tasks.

Instructors used LMS dashboards to monitor quiz completions, tailoring in-class discussions to address common challenges and ensure readiness for collaborative activities.

In-Class Activities

Face-to-face sessions bridged theoretical concepts with practical application through active and collaborative learning. Activities such as peer feedback, case studies, and gamified quizzes deepened understanding and enhanced teaching competence.

Collaborative groups formed during the first session remained consistent throughout the program, fostering com-

munity and accountability. Instructors facilitated discussions, modeled effective teaching practices, and provided feedback to support participants' instructional development.

Module 5 focused on teaching demonstrations, where groups designed lesson plans and delivered mini-tutorials. Structured peer evaluations and rubrics encouraged critical reflection, with instructors offering actionable feedback to refine teaching techniques.

Post-Class Challenges

Optional challenges extended learning beyond the classroom, encouraging participants to apply pedagogical concepts in practical contexts. Tasks included evaluating peer lesson plans and refining instructional materials, all hosted on Google Forms for efficient submission management.

Participants earned mCoins for completed challenges, with balances tracked via The Hidden Tuck Shop platform. Instructors reviewed selected submissions to provide feedback, reinforcing the connection between engagement and achievement.

Gamification Operations

The Hidden Tuck Shop platform facilitated the gamification system, providing scalable and efficient management of mCoins, rewards, and collaborative mechanisms. By automating processes while maintaining instructor oversight, the platform ensured that gamification remained engaging, transparent, and aligned with the program's educational goals.

mCoin Management

The management of mCoins combined automation and instructor-driven processes to track student participation across all program phases:

- Pre-Class Quizzes: Completion data from the LMS was exported weekly and uploaded to the platform.
- In-Class Activities: Instructors recorded participation in group activities and gamified quizzes directly into the platform's Google Sheets dashboard.
- Post-Class Challenges: Google Forms submissions automatically updated mCoin balances, streamlining the process for both students and instructors.

This hybrid approach ensured accurate tracking of engagement while minimizing administrative workload.

Reward Distribution

Rewards were fulfilled through a combination of automation and instructor in-

volvement, ensuring timely delivery and reinforcing consistent engagement:

- Online Redemption: Students redeemed mCoins for rewards via the platform which displayed real-time balances, available rewards, and leaderboards.
- Physical Rewards: Themed collectible playing cards were distributed weekly during in-class sessions, fostering community and creating moments for shared recognition.
- Digital Rewards: Digital playing cards were generated automatically upon redemption and stored on the platform for instant access.
- Tangible Benefits: Depending on the reward type, benefits were either automatically assigned based on students' selections or facilitated by instructors using redemption records.

This multi-tier and multi-component reward system balanced immediacy and personalization, motivating sustained participation while fostering a sense of accomplishment.

Collaborative Mechanisms

The coin transfer feature allowed students to allocate mCoins within or across groups, fostering resource sharing and teamwork. Students initiated transfers through the platform by specifying the recipient and the amount to be transferred, with balances updated in real time to ensure transparency and accuracy.

Instructors monitored transfer logs via the platform's Google Sheets integration, gaining insights into participation patterns and identifying opportunities to encourage collaboration or address discrepancies. By promoting mutual support and shared accountability, this feature played a key role in reinforcing community building among participants.

Instructor Oversight

The platform's centralized Google Sheets dashboard streamlined gamification management, enabling instructors to focus on facilitating learning rather than administrative tasks. The dashboard provided real-time insights through leaderboards, coin transfer logs, and redemption records, offering a comprehensive view of student engagement.

These metrics allowed instructors to monitor participation trends and adapt gamification elements to better align with participants' needs. By reducing administrative burdens, the platform enabled instructors to dedicate more time to providing feedback, fostering collaboration, and enhancing the overall learning experience.

AI Tools Integration

The two chatbots, Mr. Watson and The Secretary, were hosted on a central hub called the PDEV6800Z AI Toolbox, named after the course code for our GTA training program. This hub was accessed through the LMS and provided consistent support for both students and instructors throughout the program.

The optional post-class challenges leveraged these custom-designed AI tools to expose students to cutting-edge technologies and encourage reflective practice. For instance, in one challenge, students used Mr. Watson or other AI tools to generate five lesson ideas and critically evaluate their pedagogical feasibility and alignment with intended learning outcomes.

The Secretary automated routine queries related to deadlines, schedules, and procedural clarifications, providing students with real-time logistical support and instant feedback. This automation reduced administrative burdens for instructors, allowing them to focus on facilitating learning and providing targeted guidance.

Methodology

This case study investigates the implementation of an innovative GTA training approach at a research-intensive university in Hong Kong. The study examines six sections (n=449) taught by the first author during Fall 2024. While this design allowed for consistent implementation of the innovative pedagogical approach within these sections and facilitated systematic data collection, we acknowledge the potential for researcher bias due to the first author's role as both instructor and researcher. To mitigate such concerns, several measures were implemented: (1) All core content, learning materials, assessment guidelines, and gamification mechanics were standardized across all 10 sections of the program; (2) Quantitative engagement metrics were collected automatically through The Hidden Tuck Shop platform, eliminating subjective data recording or interpretation at the point of collection; (3) Post-course surveys were administered through the university's anonymous system outside of class time, with responses inaccessible to the instructor until after final grades were submitted; and (4) Multiple data sources (platform analytics, survey responses, and student artifacts) were triangulated to cross-validate findings, reducing reliance on any single data type. Despite these measures, the potential influence of instructor effects is further discussed in the Limitations section.

Participants

The study included 449 newly admitted, full-time RPg students enrolled in the mandatory GTA training program during Fall 2024. Table 1 presents the demographic characteristics of participants. The sample comprised predominantly PhD students (70.2%) with MPhil students making up the remaining 29.8%. Participants represented 27 departments across five schools, with the School of Engineering contributing the largest proportion (54.6%), followed by the School of Science (26.3%). This diverse representation across disciplines reflects the university-wide nature of the program and provides important context for understanding the cross-disciplinary collaborative behaviors reported in our findings.

Table 1

Participant Demographics (n=449)

Characteristic	n (%)
Study Level	
PhD	315 (70.2)
MPhil	134 (29.8)
School Affiliation	
School of Engineering	245 (54.6)
School of Science	118 (26.3)
Academy of Interdisciplinary Studies	57 (12.7)
School of Business & Management	18 (4.0)
School of Humanities & Social Science	11 (2.4)
Section Distribution	
Six parallel sections	72-78 per section
Disciplinary Representation	
Total departments represented	27
Top 3 departments:	
Computer Science & Engineering	79 (17.6)
Electronic & Computer Engineering	64 (14.3)
Life Science	38 (8.5)

Data Collection

Multiple data sources were used to comprehensively evaluate the program's implementation and its impact on participants. Platform analytics from The Hidden Tuck Shop provided objective engagement metrics, including records of challenge completions, reward redemptions, and mCoin transfers, capturing real-time patterns of student engagement with gamification elements and collaborative behaviors throughout the program.

An optional online post-course survey (n=289, response rate 64.4% of the 449 students in the six sections studied) was administered via Qualtrics to collect comprehensive feedback upon completion of the program. The primary purpose of this post-course survey was to evaluate participants' experiences with the innovative components of the GTA training program (blended learning, gamification, AI tools), assess their self-reported teaching confidence and motivation following the course, and gather actionable feedback for future iterations. The survey instrument was developed by integrating custom-designed questions tailored to the specific features of the program (such as the usability of The Hidden Tuck Shop and perceptions of the AI chatbots) with items adapted from the Expectancy-Value-Cost (EVC) Survey (Hulleman et al., 2016) to measure constructs related to student motivation, perceived value, and cost. The survey was comprised of the following sections:

1. *Gamification Usability and Experience*: This included 5 items on the usability of gamification features (GEOU_1-5) and 7 items on the perceived impact of gamified elements on learning engagement (GE_1-7). Both sets of items utilized a 7-point Likert scale (1=Strongly Disagree to 7=Strongly Agree).
2. *AI Tool Usage and Effectiveness*: This section contained multiple items examining participants' adoption patterns and usage strategies for AI tools, including the custom-built chatbots. Perceived usefulness of AI for various academic tasks (e.g., AI_6_1 to AI_6_3) was rated on a 5-point Likert scale (1=Not Useful at All to 5=Very Useful), and confidence in using GenAI tools was assessed on a 5-point scale (1=Not confident at all to 5=Very confident). Open-ended questions also solicited feedback on challenges and integration suggestions.
3. *Teaching Confidence and Skill*s: Ten items (MAf_1_1V to MAf_1_10E) evaluated self-reported confidence in core teaching competencies, such as implementing active learning strate-

gies, lesson planning, and providing constructive feedback. These items used a 6-point Likert scale (1=Strongly Disagree to 6=Strongly Agree).

4. *Overall Engagement and Motivation*: Participants rated their overall course engagement (MAf_2_1a) on a 5-point Likert scale (1=Not Engaging to 5=Engaging). Qualitative reflections on their engagement levels and any changes in motivation were captured through open-ended questions (e.g., MAf_2_1b, MAf_2_2b).
5. *Open-ended Reflections*: Additional open-ended questions sought feedback on specific rewards (R1, R2) and general suggestions for course improvement (Imp_1, Imp_2).

The varied Likert scales were chosen to suit the specific constructs being measured in each section. The combination of structured quantitative items and open-ended qualitative questions in the post-course survey provided both metrics for statistical analysis and rich insights for thematic analysis, offering a comprehensive understanding of usability, engagement, self-perceived teaching confidence, and overall learning experiences.

Analysis Approach

A mixed-methods approach was employed to integrate quantitative and qualitative data, providing a comprehensive understanding of the program's implementation and outcomes.

Quantitative Analysis

Descriptive statistics were used to examine engagement and participation patterns, focusing on metrics such as challenge completion rates, reward redemptions, and mCoin transfers alongside structured survey responses. Platform analytics data were analyzed to identify patterns of individual and group engagement with optional activities and gamification elements.

Qualitative Data Analysis

Open-ended survey responses underwent systematic thematic analysis. Two question sets were analyzed: (1) reasons for rating the engagement levels (MAf_2_1b), and (2) initial motivation for attending class (MAf_2_2a) and changes in motivation after taking the course (MAf_2_2b).

For engagement reasons, they were coded by identifying the primary factor students mentioned for their engagement rating. Categories emerged from the data and were organized into four main themes: Pedagogical Design Elements (e.g., active learning, activities, course structure), Motivational Design Elements (e.g., gamification, group work), Contextual Factors (e.g., time constraints, instructor, mandatory nature), and Learning Experience (e.g., skill

acquisition, enjoyment, interest). A total of four responses were deemed uncodable (e.g., blank, random characters, or single, non-substantive words like "no" or "NA") and thus excluded from the count of responses used to calculate specific theme frequencies for engagement reasons (final n for engagement theme analysis = 285).

For motivational questions, responses about initial motivation were grouped by the primary reason stated for attending (e.g., wanting to improve teaching skills, course requirement, low interest). Post-course motivation changes were categorized based on the type of change described (e.g., increased interest, new perspective, no change).

To ensure coding reliability across all open-ended qualitative data, the second author, who was not involved in teaching the course sections, independently coded a randomly selected 20% of responses for engagement reasons (MAf_2_1b, n=58), initial motivation categories (MAf_2_2a, n=58), and motivational change categories (MAf_2_2b, n=58). Inter-rater reliability was assessed using both percent agreement (PA) and Cohen's Kappa (K). For engagement reasons, main theme coding achieved a PA of 93.1% (K = 0.888) and subtheme coding a PA of 89.7% (K = 0.878). For motivational questions, initial motivation categories yielded a PA of 84.5% (K = 0.758), while motivational change categories resulted in a PA of 91.4% (K = 0.877). According to established benchmarks (e.g., Landis & Koch, 1977), these Kappa values indicate substantial to almost perfect agreement across all coding frames. All coding discrepancies identified during this process were resolved through discussion between the two coders to reach consensus before the first author completed the coding of the full dataset.

Quantitative and qualitative findings were integrated to provide a comprehensive understanding of how different design elements contributed to engagement and learning outcomes. Quotes were selected to represent the full spectrum of participant experiences, including both positive outcomes and challenges encountered.

Results

The implementation of the innovatively designed GTA training program yielded notable outcomes in student participation, engagement with gamified elements, and key self-reported learning indicators. An overview of quantitative findings is presented in Table 2. Summaries of the thematic analysis, detailing student-reported reasons for engagement, initial motivations, and motivational changes, are provided in Tables 3, 4, and 5, respectively. The subsequent sections offer a detailed exploration of these integrated results.

Table 2

Summary of Key Participation, Engagement, Learning Outcomes, and GenAI Tool Usage

Metric Category	Measure	Value
A. Participation Patterns		
Individual Challenge Completion (n=449)	No optional challenges completed	185 (41.2%)
	1 challenge completed	100 (22.3%)
	2 challenges completed	85 (18.9%)
	All 3 challenges completed	79 (17.6%)
Group Challenge Completion (n=72)	None (0 challenges)	1 (1.4%)
	Low (1-3 challenges completed)	23 (32.0%)
	High (4-6 challenges completed)	38 (52.7%)
	Full (all 7 challenges completed)	10 (13.9%)
	Groups completing ≥1 challenge	71 (98.6%)
B. Gamification Engagement		
Platform Utilization	Total group reward redemptions	129
	Most popular group reward ("Champ Select")	56 groups (77.8%)
	Second most popular group reward ("Teleport")	49 groups (68.1%)
	Total individual reward redemptions	184
	Most popular individual reward ("Mystery Munchies")	125 redemptions
	Second most popular individual reward ("Glory in Death")	50 redemptions
Collaborative Behaviors	mCoin transfer transaction	59
	Total mCoins transferred	18,746
	Average mCoins per transaction	318
	Within-group transfers	49 (83.1%)
	Cross-section transfers	9 (15.3%)

Metric Category	Measure	Value
C. Self-Reported Outcomes (n=289)		
Engagement Level	Engaged/Somewhat Engaged	236 (81.7%)
	Neutral	(14.5%)
	Disengaged	11 (3.8%)
Teaching Confidence	Confident in active learning strategies	271 (93.8%)
	Confident in lesson planning	274 (94.8%)
	Confident in providing feedback	272 (94.1%)
Technology Acceptance	Found gamification platform easy to use	227 (78.6%)
	Found challenge submission straightforward	240 (83.1%)
	Agreed rewards enhanced collaboration	239 (82.7%)
D. GenAI Tool Usage & Perceptions (n=289)		
Reported using GenAI tools for any aspect of the course	Yes	224 (77.5%)
	No	65 (22.5%)
Reported Tool Use (among users, n=224)	ChatGPT (OpenAI)	132 (58.9%)
	"Mr. Watson" (the custom-built AI chatbot)	103 (46.0%)
Confidence & Use Cases (among users, n=224)	Confidence in effective use (M, SD)	3.59 (0.85)
	Use Case: Summarizing or explaining course materials	92 (41.1%)
	Use Case: Refining languages or translating lesson plan	86 (38.4%)
Perceived usefulness of GenAI tools for course aspects (M, SD) on a 5-point scale where 1=Not Useful at All, 5=Very Useful (among users, n=224)	Clarifying Concepts	4.09 (0.89)
	Inspiring Ideas	3.99 (0.88)
	Creating Materials	4.09 (0.88)
	Enhancing Quality	4.01 (0.93)
Barriers to Use (among non-users, n=65)	Top reason: "Traditional tools are better"	16 (24.6%)

Table 3

Main Themes Identified for Engagement Reasons (n=285 codable responses)

Main Theme	%
Learning Experience	31.1
Pedagogical Design Elements	30.4
Motivational Design Elements	28.1
Contextual Factors	10.4

Table 4

Distribution of Participants' Initial Motivation for Attending the Course (n=289)

Initial Motivation Category	%
Intrinsic Teaching Interest	35.6
Practical/External Motivation	31.8
Low/Reluctant Motivation	14.5
Mixed/Unclear	18.1

Table 5

Distribution of Reported Changes in Motivation After Course Completion (n=289)

Initial Motivation Category	%
Enhanced Motivation	42.2
Transformed Perspective	6.2
Sustained Motivation	39.1
Decreased/Challenged	1.4
No Change Stated	11.1

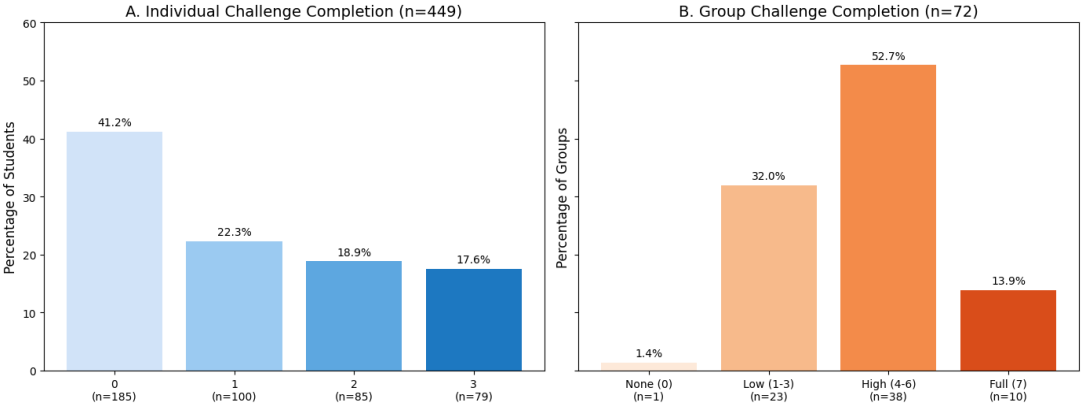
Engagement Patterns and Platform Utilization

Analysis of individual and group participation in optional post-class challenges revealed distinct engagement patterns (see Figure 3). At the individual level (n=449), participation showed considerable variation. As shown in Panel A, while 41.2% (n=185) of students did not complete any optional challenges, the

remaining 58.8% (n=264) completed at least one optional challenge. Specifically, 22.3% (n=100) completed one challenge, 18.9% (n=85) completed two challenges, and 17.6% (n=79) completed all three available tasks.

Figure 3

Distribution of Optional Challenge Completion by Individuals and Groups



Panel A shows individual student completion rates (n=449) for three available challenges. Panel B shows group completion rates (n=72) for seven available challenges, grouped into four categories: None (0 challenges), Low (1-3 challenges), High (4-6 challenges), and Full completion (7 challenges).

In contrast, group participation (n=72) showed remarkably high engagement levels. As illustrated in Panel B, nearly all groups (98.6%, n=71) completed at least one optional challenge. The majority of groups (52.7%, n=38) demonstrated high engagement by completing 4-6 challenges, while 13.9% (n=10) achieved full completion of all seven tasks. Only one group (1.4%) did not participate in any optional challenges. A student reflected on this collaborative effort: "*After class, our team makes efforts together to finish the post-class activities,*" highlighting how group accountability fostered consistent engagement.

This high level of engagement was further reflected in platform utilization. The Hidden Tuck Shop, the program's digital gamification platform, recorded 129 group reward redemptions. Of the 72 groups in this case study, "Champ Select" was the

most popular reward, redeemed by 77.8% of groups (n=56). This reward allowed teams to select their teaching demonstration facilitators. Similarly, "Teleport," which enabled teams to choose their preferred demonstration time slot, was redeemed by 68.1% of groups (n=49).

Individual rewards were redeemed 184 times. The most popular were "Mystery Munchies" (125 redemptions), offering random snacks from a capsule toy machine, and "Glory in Death" (50 redemptions), allowing retakes of missed or failed pre-class quizzes. These data reflect participants' active engagement with the reward system, highlighting a mix of practical and enjoyable incentives.

Post-course surveys (n=289, response rate 64.4%) further validated these findings, with 81.7% of respondents reporting being "Engaged" or "Somewhat Engaged." Thematic analysis of engagement reasons revealed that students attributed their engagement to multiple integrated factors, with the overall learning experience (31.1%) and pedagogical design elements (30.4%) most frequently cited. As one participant explained: "*The activities, discussions, and use of interactive tools kept me actively involved and motivated to participate.*" Another noted the integrated nature of the design: "*The quiz required before class, the rich classroom activities, and the bonus set after class make me feel very engaged, especially collecting mCoins to redeem prizes.*"

However, students also acknowledged real constraints, with 10.4% citing time and workload as primary concerns. As one participant noted: "*Happy classes, many interesting activities, but I really do not have enough time for homework,*" reflecting the ongoing challenge of balancing engaging professional development with graduate students' multiple responsibilities.

Community Development and Collaborative Learning

The program effectively fostered peer connections and collaborative learning through its innovative platform features and focus on group activities in program design. Analysis of the mCoin transfer system revealed significant resource sharing behaviors, with 59 transactions totaling 18,746 mCoins recorded across the semester. Most transfers (49) occurred within groups, reflecting strong intra-team collaboration. Additionally, nine inter-section transfers were recorded, suggesting that collaboration extended beyond immediate teams. Transfer amounts ranged from 1 to 2,400 mCoins, with an average of 318 mCoins per transaction, highlighting diverse resource-pooling behaviors.

Collaborative engagement was fur-

ther evident in optional activities, with 94.4% of groups collaborating on two or more post-class challenges, demonstrating sustained teamwork beyond baseline participation. This collaborative dynamic was supported by the reward system, with 82.7% of survey respondents agreeing that it enhanced peer discussions and cooperation.

Thematic analysis of open-ended responses explaining student engagement further illustrated these collaborative experiences. The gamified group achievements, for instance, fueled collective effort, with one participant sharing: "*Because our group earned the most mCoins, we worked hard for this course,*" illustrating how collective achievements motivated continued engagement. Student reflections also strongly emphasized the program's role in building cross-disciplinary connections and fostering relationships. One participant noted: *"This is a great chance for me to communicate with students from different departments and learn from each other,"* while another shared how the process solidified group bonds: "*During the whole process, we became a real team, working together and getting to know each other better*." Furthermore, some highlighted the inclusivity of group activities: *"It allows all the members in the group to participate."* These experiences point toward the development of a learning community that extended beyond individual skill acquisition.

While collaboration was largely successful, some students noted typical group work challenges, such as inactive members or varying engagement levels. As one student observed: *"The engagement of this course depends somewhat on the interactivity of group mates."*

Teaching Development and Learning Experience

Post-course surveys revealed consistently high confidence levels across key teaching competencies, reflecting positive outcomes in developing essential GTA skills (see Table 2). For instance, confidence in implementing active learning strategies was expressed by 93.8% of respondents, with similar levels reported for lesson planning (94.8%) and providing constructive feedback (94.1%). These consistently high ratings suggest that the program effectively addressed core teaching competencies.

These confidence ratings aligned with qualitative findings from the engagement analysis, where 10.0% of students specifically cited "Skill/Knowledge Development" as their primary engagement factor. Students frequently connected their learning to future teaching applications, with

one participant sharing: *"The course provided hands-on activities and gave me lots of ideas for delivering similarly engaging tutorials in the future." Another noted, "This course laid a good foundation for me to work as a teaching assistant in the future."*

The program's pedagogical approach itself served as a teaching model. Analysis revealed that 15.6% of students highlighted active learning methods as their primary engagement driver, with many noting how the structure provided transferable examples. One participant remarked: "*The course itself is a good example for us to engage active learning," while another emphasized: "The lessons are interactive and require adequate thinking, which trained my mindset for how to teach.*"

This perceived development in teaching competence and understanding resonated with shifts in student motivation (see Tables 4 and 5 for full distributions). Notably, 42.2% of respondents reported "Enhanced Motivation" after completing the course, and an additional 6.2% described a "Transformed Perspective" on teaching. For example, a student articulated a transformed understanding of the TA role: "*A TA is not only [to] assist the lecturer with assignments or other administrative affairs but also [to] design a lesson carefully and encourage students to achieve learning goals*". While a substantial portion (39.1%) reported "Sustained Motivation", often maintaining an initial interest, the qualitative data suggests the course positively influenced many participants' outlook on teaching. It is worth noting, however, that a small fraction of respondents (1.4%) reported that their motivation was challenged or decreased, often citing external pressures such as, "*If I am not stressful for the graduation requirements, I will very enjoy the course.*"

The integration of technology further enhanced the learning experience by improving resource accessibility and simplifying administrative processes. Usability ratings demonstrated the effectiveness of these tools, as 78.6% of students found the Hidden Tuck Shop platform easy to navigate, and 83.1% reported that the challenge submission system was straightforward to use. One participant reflected on the motivational aspect: "*Successfully completing assignments and solving challenges with the tools boosted my confidence. This sense of achievement motivated me to explore and experiment further.*"

Generative AI Tool Usage and Perceptions

Beyond the gamification platform and collaborative elements, the program's integration of AI tools represented another key

innovation in supporting large-scale professional development. Post-course survey data (n=289) provided insights into participants' engagement with and perceptions of Generative AI (GenAI) tools for aspects of the course (see Table 2, Section D for full metrics).

A substantial majority of participants (224 students, 77.5%) reported using GenAI tools. Among these users (n=224), the most frequently mentioned tools were OpenAI's ChatGPT (132 users, 58.9%) and the custom-built pedagogical chatbot, "Mr. Watson" (103 users, 46.0%). For the 65 students (22.5%) who did not utilize GenAI tools, the top reason cited was a belief that "*Traditional tools are better*" (16 students, 24.6% of non-users), with other reasons including prior negative experiences or lack of familiarity.

Overall, students expressed moderate confidence in their ability to use GenAI tools effectively for academic purposes, with a mean score of 3.59 (SD=0.85) on a 5-point scale. The primary reported use cases among GenAI users (n=224) were "Summarizing or explaining course materials" (92 students, 41.1%) and "Refining languages or translating lesson plan" (86 students, 38.4%).

Regarding the perceived usefulness of GenAI for specific course-related tasks (rated on a 5-point scale where 1=Not Useful at All, 5=Very Useful), students found them quite beneficial. Mean usefulness ratings were consistently positive: 4.09 (SD=0.89) for "Clarifying Concepts," 3.99 (SD=0.88) for "Inspiring Ideas," 4.09 (SD=0.88) for "Creating Materials," and 4.01 (SD=0.93) for "Enhancing Quality" of their work.

In terms of overall impact, open-ended responses indicated that many students found GenAI tools beneficial to their learning experience in the course. For example, one GTA highlighted how AI helped apply course concepts directly to teaching preparation: "*It help me to write down my ideas in a better way by integrating the key words that we learn during the course into the lesson plan.*" Others pointed to significant gains in efficiency and the ability to focus on more complex aspects of their work. As one student noted, "*GenAI tools provided high-quality foundational content early in tasks, reducing time spent on searching and organizing information, which allowed more time for deep thinking and discussion.*" The role of AI in idea generation was also valued, with a participant sharing, "*When I don't have an idea, ChatGPT provides me with many examples to inspire me in preparing more interesting materials.*" While generally positive, some students also expressed a thoughtful or cautious perspective on relying on these

tools, with one stating, "*It is a good way to help us but we cannot trust it totally.*"

Together, the integrated blended learning structure, engaging gamification, and supportive AI tools appeared to provide a cohesive learning experience that combined pedagogical innovation with practical application. The program showcased the potential of technology to enhance active pedagogy while modeling effective teaching practices. As one participant summarized, "*The course is quite engaging, offering a solid blend of relevant content and a clear teaching style that captures interest.*" The strategic integration of AI tools further amplified these effects by providing scalable support for competence development through on-demand clarification and assistance, while maintaining learner autonomy through optional, self-directed engagement with these resources

Discussion

This case study explores how the systematic integration of blended learning, gamification, and AI support can enhance mandatory professional development at scale. While previous research has highlighted the challenges of engaging GTAs in required training (DeChenne et al., 2012; Saxena et al., 2022), our findings suggest potential pathways for transforming these constraints into opportunities for meaningful learning and community building. The emergence of well-coordinated collaborative behaviors and cross-disciplinary learning patterns offers insights into how carefully structured technology integration might support both individual development and collective growth in professional development contexts.

Theoretical Implications

This study's findings offer contributions to theoretical understanding by providing empirical evidence on how Self-Determination Theory (SDT) and the Mechanics-Dynamics-Aesthetics (MDA) framework operate within the challenging context of large-scale, mandatory, technology-enhanced professional development.

Extending Self-Determination Theory (SDT) in Mandatory Educational Settings

While SDT research often highlights how external requirements diminish intrinsic motivation, our findings suggest how thoughtful design might nurture basic psychological needs even within mandatory frameworks.

- *Operationalizing Autonomy through Bounded Choice*: This study extends SDT by revealing how bounded choices within mandatory contexts can foster perceived autonomy. Our study

observed remarkably high voluntary engagement with optional challenges (98.6% of groups) and strategic use of choice-based rewards, such as selecting presentation slots. These findings suggest that providing learners with meaningful options like choosing their level of engagement beyond core tasks or influencing procedural aspects like scheduling can cultivate volition and drive engagement, even within a compulsory program structure.

- *Supporting Competence and Relatedness at Scale*: Our findings show how structured design elements can systematically foster competence and relatedness across a large, diverse cohort. The program's phased blended learning structure and immediate feedback mechanisms like mCoins systematically supported competence development. with participants reporting high teaching confidence post-program (93.8% for active learning strategies). Furthermore, relatedness was fostered not merely through encouraged interaction but via designed mechanics. The mCoin transfer system, for example, facilitated sophisticated peer support, including unexpected inter-section transfers. This, coupled with qualitative accounts of forming "a real team" and valuing cross-departmental connections, demonstrates how specific technological affordances can structurally promote relatedness, rather than leaving it to chance, which is a crucial insight for scaling such programs in diverse cohorts.

Extending the MDA Framework in Adult Professional Development

Our implementation provides empirical insights into MDA's application in adult professional development contexts, where its application has been less explored.

- *From Mechanics to Educational Dynamics*: Beyond surface-level engagement, the mCoin transfer feature (a "mechanic") was associated with emergent strategic collaborative behaviors (a "dynamic"), evidenced by 59 transfers totaling 18,746 mCoins. While the exact intent of every transfer was not tracked, the prevalence of within-group transfers alongside inter-section support suggests these dynamics extended beyond mere point accumulation to encompass resource management for collective goals and potentially peer support, illustrating how carefully designed mechanics can foster complex skills like resource management and teamwork.
- *Multi-Dimensional Aesthetics for Mandatory Training*: Our multi-tier

and multi-component reward system reveals varied engagement patterns among adult learners in mandatory professional contexts. High redemption rates for utility-focused rewards (e.g., "Champ Select": 77.8% of groups) alongside engagement with more intrinsically playful elements (e.g., "Mystery Munchies": 125 redemptions) indicate that participants valued both practical benefits and enjoyable experiences. This finding suggests that effective gamification in such contexts should cater to a spectrum of aesthetic experiences, from achievement and practical problem-solving (aligning with aesthetics like "Challenge" or "Submission" in a broader sense of system mastery) to pure enjoyment and social connection (aligning with "Sensation" or "Fellowship"), rather than focusing narrowly on a single motivational lever.

Implications for Theories of AI in Educational Support

The findings related to Generative AI tool usage offer several insights for theories concerning AI integration in professional development. The high adoption rate of GenAI tools (77.5% of survey respondents) suggests a general receptiveness among GTAs to leveraging these technologies, aligning with broader trends of AI acceptance in higher education. Notably, the substantial use of both the custom-built pedagogical chatbot, "Mr. Watson," and general-purpose tools like ChatGPT (used by 46.0% and 58.9% of GenAI users respectively) may indicate that learners in such programs benefit from a "toolkit" approach. This suggests that theoretical models of AI integration should consider the value of providing both context-specific, curated AI resources and access to broader tools that learners can adapt to varied needs.

The primary use cases reported by GTAs, such as "Summarizing or explaining course materials" and "Refining languages or translating lesson plan", and the high perceived usefulness of GenAI for tasks like "Clarifying Concepts" (Mean=4.09) and "Creating Materials" (Mean=4.09) empirically support theoretical assertions of AI as a cognitive tool for scaffolding understanding and enhancing productivity (e.g., Wollny et al., 2021; Okonkwo & Ade-Ibijola, 2021). For instance, qualitative feedback highlighted AI's role in helping GTAs integrate course keywords into lesson plans, effectively bridging theoretical learning with practical teaching preparation. This aligns with theories positing AI's potential to support the application of learned concepts.

However, the finding that students ex-

pressed only moderate confidence in using GenAI tools effectively (Mean=3.59), despite rating their usefulness highly, presents a nuanced point for AI integration theories. This potential gap between perceived value and self-efficacy could suggest that while theories on AI's utility are being validated, practical implementation also needs to consider theories of digital literacy development and address the learning curve associated with effective and critical AI use. The cautionary student reflection that AI is "*a good way to help us but we cannot trust it totally*" further underscores the importance of integrating critical AI literacy into professional development, moving beyond instrumental use to foster responsible and discerning engagement with AI tools. This supports emerging theoretical discussions on the necessity of human oversight and critical evaluation in human-AI collaboration for learning and professional tasks.

Theoretical Synthesis

These findings contribute to a deeper theoretical understanding by revealing the synergistic interplay between SDT, MDA principles, and the strategic application of AI in educational support, when applied to the often-challenging domain of large-scale, mandatory professional development. Specifically, our work demonstrates how carefully designed game "mechanics" and "dynamics" (MDA) can serve as practical vehicles for satisfying basic psychological "needs" (SDT), while AI tools offer scalable support for areas like competence development and access to information. For instance, choice-based reward systems (an MDA mechanic) directly supported "autonomy", while collaborative challenges and resource sharing (MDA dynamics) fostered "relatedness" and, through successful group outcomes, "competence." The observed patterns of bounded autonomy leading to high voluntary engagement, strategic collaborative behaviors emerging from simple mechanics, and multi-dimensional aesthetic appreciation suggest that these frameworks, when thoughtfully integrated with appropriate technological support like AI, can transform compulsory training into an experience perceived as valuable and motivating, offering a model where structural design enables, rather than constrains, psychological need fulfillment at scale.

Practical Implications

Integrated Design for Scale

Our findings demonstrate how an integrated design, combining blended learning, gamification, and AI support, can balance scalability with personalization in profes-

sional development. The following strategies emerged from our implementation:

- *Establish Clear Pathways*: Design engagement structures that align with learning objectives, including core requirements, optional extension activities, and transparent progression paths that connect tasks to outcomes.
- *Develop Support Structures*: Provide administrative tools and clear guidance for both instructors and participants. Establish mechanisms for feedback while fostering community development organically.
- *Plan for Sustainable Scaling*: Start with essential components and progressively add features to enhance engagement. Monitor adoption, gather feedback, and adjust based on participant needs.

These strategies emphasize the importance of aligning design features with program goals to address the logistical and motivational challenges of large-scale training.

Balancing Structure and Flexibility

The findings suggest strategies for maintaining engagement in mandatory training programs:

- *Multi-level Reward Systems*: Combine individual and group incentives that align with learning objectives, fostering both personal agency and teamwork.
- *Flexible Challenge Structures*: Allow participants to extend their learning based on interest and capacity, encouraging deeper engagement without compromising core requirements.
- *Clear Connections to Professional Development Goals*: Ensure optional activities are meaningful, supporting skill-building and career preparation.
- *Structured Support for Collaboration*: While fostering organic teamwork, provide clear guidelines for group-based activities and consider implementing mechanisms to proactively address common challenges, such as uneven participation or conflict resolution, especially in diverse and mandatory settings.

By aligning flexibility with structured goals, these strategies promote autonomy and motivation in diverse cohorts.

Technology Integration Considerations

Experience from our implementation highlights several considerations for integrating technology in professional development:

- *User-Centered Design*: Design user experiences based on familiar interfaces to reduce technical barriers and

support accessibility for participants with varying proficiency levels.

- *Integration with Existing Tools*: Leverage familiar systems like Google Sheets to streamline program management and improve adoption by both students and instructors.
- *Automated Tracking with Human Oversight*: Combine automated processes with instructor review to ensure program quality while reducing administrative burdens.
- *Strategically Provide and Support a "Toolkit" of AI Resources*: Recognize that GTAs may benefit from a range of AI tools. Offer guidance on leveraging both program-specific custom tools (like "Mr. Watson") and general-purpose AI applications, helping GTAs select the best tool for specific pedagogical and administrative tasks encountered during their training and TA duties.
- *Cultivate Comprehensive AI Literacy*: Addressing the observed gap between high perceived AI usefulness and moderate user confidence, implement targeted training for GTAs that moves beyond basic tool usage to foster effective application strategies, critical evaluation of AI-generated content, and responsible engagement with AI, including discussions on its limitations and ethical considerations highlighted in student feedback.

These insights suggest that thoughtful technology integration, whether for gamified platforms or AI assistance, requires a multifaceted approach focusing on usability, efficient management, and empowering users with the skills for critical and effective engagement to enhance professional development at scale.

Emergent Patterns

Unexpected Collaborative Behaviors

The platform's gamification features, such as mCoin transfers, revealed unexpected patterns of strategic collaboration. Participants developed sophisticated approaches to pooling resources for collective benefits, highlighting how gamification mechanics can encourage coordination and teamwork. These behaviors demonstrate the potential for well-designed features to extend collaboration beyond immediate teams, fostering new forms of peer interaction and collective problem-solving.

Collaborative Learning Across Disciplines

Group-based learning activities, including teaching demonstrations and collaborative challenges, leveraged the diversity of participants' disciplinary backgrounds, creating opportunities for rich peer learning. By providing structured collaborative tasks and flexible engagement pathways, the pro-

gram transformed diversity from a logistical challenge into a pedagogical strength. These findings suggest that well-designed group activities can foster interdisciplinary exchanges, supporting deeper understanding and collaborative growth.

Strategic Resource Management

Participants demonstrated strategic planning in reward redemptions and resource allocation, suggesting that technology-enhanced gamification can foster decision-making and resource management skills relevant to broader professional contexts. Features such as mCoin transfers and redeeming rewards using the earned mCoins encouraged participants to optimize resources, illustrating how thoughtfully integrated technology can support the development of transferable skills like strategic thinking and planning.

Implications And Future Directions

Implementation Insights

Our experience implementing this integrated approach in a large-scale GTA training program offers several insights that may be relevant for similar contexts.

Progressive Integration

Separating required and optional components allowed progressive integration of engagement elements while maintaining core learning objectives. This design provided flexibility for institutions to adapt based on participant feedback and available resources, enabling sustainable scaling while managing resource constraints.

Technology Selection and Integration

When implementing technology-enhanced professional development, institutions should consider both user experience and administrative efficiency. Familiar interface designs and integration with existing institutional tools can reduce barriers to adoption while enabling efficient program management at scale. However, successful implementation requires ongoing monitoring of both system performance and user needs.

Purpose-Driven Design Integration

Professional development programs should ensure that technological and engagement features directly support learning objectives rather than being added for their own sake. This might involve evaluating how each component contributes to teaching development, considering the balance between automation and human interaction, and ensuring that engagement mechanisms enhance rather than distract from core learning goals. Such alignment helps maintain program focus while scaling support.

Contextual Enablers and Constraints

Several institutional factors shaped the success of our implementation.

Institutional Structures

As a central teaching support unit responsible for university-wide GTA training, we benefited from established structures that brought together participants from diverse disciplines. This centralized position facilitated consistent scheduling and cross-disciplinary interaction but required attention to varying departmental needs and expectations.

Mandatory Nature of the Program

While the requirement constrained initial motivation, it also created opportunities for peer learning and community building across disciplines. The large cohort size (over 800 students annually) necessitated efficient systems but also provided valuable data for analyzing engagement patterns.

Resource Constraints

Limited instructional staff led to reliance on automated systems and peer learning mechanisms. Technology decisions were influenced by the need to integrate with existing university systems, fostering creative solutions that emphasized scalability and sustainability in professional development design.

Limitations

While this study provides valuable insights, several limitations should be considered when interpreting the findings:

Study Design Limitations

The chosen case study methodology, while offering rich, contextualized insights, has inherent limitations affecting the scope and generalizability of the findings:

- *Single-Institution Context*: The implementation was conducted in a single research-intensive university in Hong Kong, limiting the generalizability of findings to other institutional or cultural settings. Cross-institutional validation could strengthen the applicability of our design principles.
- *Short-Term Outcome Measures*: Our evaluation focused on immediate engagement and self-reported confidence measures. Longitudinal studies tracking sustained professional growth and teaching performance would provide a more comprehensive understanding of the program's long-term impact.
- *AI Scope*: While our AI tools provided valuable support, they focused primarily on logistical support and

basic pedagogical guidance. Future research could explore advanced applications, such as adaptive learning systems or AI-driven peer feedback, to enhance the depth of personalized support. Furthermore, while this study collected feedback on the pedagogical chatbot ("Mr. Watson") and general generative AI tool usage, specific data on the perceived utility or impact of the administrative chatbot, "The Secretary," was not explicitly solicited in the post-course survey. Consequently, its distinct contribution to streamlining administrative tasks or providing logistical support from the students' perspective could not be detailed in this study, representing an area for future investigation. Additionally, the 22.5% of participants who did not use GenAI tools represent a significant minority whose learning experience may have differed from the majority. Understanding barriers to AI adoption and designing alternative support mechanisms for these learners remains an important consideration for future implementations.

Potential Confounding Factors

Several factors, inherent to the study's context and execution, may have influenced our positive outcomes beyond the intervention itself:

- *Potential Instructor Effects*: The first author taught the six sections examined in this case study. Despite standardized content and automated data collection, the instructor's investment in the innovation and understanding of the program's design principles could have unconsciously influenced delivery and student engagement. Future research should include sections taught by multiple instructors to better isolate the effects of the innovative design from instructor-specific factors. Additionally, employing external evaluators for qualitative data analysis could further reduce potential bias in interpretation.
- *Participant Characteristics*: While we have presented demographic data, the specific cohort of Fall 2024 RPg students may have possessed unmeasured characteristics (e.g., baseline levels of technological proficiency, intrinsic motivation for pedagogical training, or prior teaching experiences) that could have uniquely contributed to their engagement and the observed outcomes. These characteristics might not be representative of all GTA cohorts.
- *Institutional Factors*: The unique environment of HKUST, including its centralized teaching support unit, the mandatory nature of its large-scale GTA training, and specific resource allocations available for this initiative,

likely contributed to the program's successful implementation and positive outcomes. These supportive institutional elements may not be present in other institutions, potentially confounding the observed effects attributed purely to the intervention design and impacting direct replicability.

Despite these limitations, this study provides valuable insights into how integrated technology-enhanced approaches can address common challenges in mandatory professional development at scale.

Future Directions

Our implementation suggests several promising areas for future research:

Longitudinal Impact

Studies tracking teaching performance and professional development outcomes over time could provide valuable insights into the long-term impact of integrated training approaches. Such research might explore how elements like resource-sharing mechanisms and gamified rewards influence sustained professional growth.

Cross-Institutional Applications

Research examining the transferability of our design principles across different institutional settings could refine professional development frameworks internationally. Understanding how contextual factors influence adoption and outcomes would be particularly valuable.

Addressing Diverse Learner Needs

Investigating strategies for further tailoring content or providing differentiated pathways to address the diverse disciplinary needs and prior experiences of GTAs within a large-scale program. This could involve exploring modular designs or more flexible learning journeys that cater to specific GTA roles and subject areas.

Advanced AI Integration

While our AI implementation focused on logistical and basic support functions, future research could explore more sophisticated applications. For example, AI-driven peer feedback systems or teaching simulations could enhance the scalability of personalized learning while preserving meaningful human interaction.

Collaborative Dynamics and Community Building

Deeper analysis of collaborative behaviors, such as mCoin transfers and interdisciplinary interactions, could inform how technology-enhanced environments foster sustainable professional learning communities. Investigating the development of cross-disciplinary networks and their long-

term impact on teaching practices could provide valuable insights.

Future research in these areas would benefit from mixed-methods approaches that combine quantitative measures of engagement and effectiveness with qualitative insights into participant experiences and professional growth.

Conclusion

This case study reveals how purposeful integration of blended learning, gamification, and technology can address a persistent challenge in higher education: engaging GTAs in mandatory professional development at scale. Our implementation achieved notable outcomes, with high voluntary participation (97.6%) and sustained engagement (81.7%), while fostering unexpected patterns of collaborations and innovative peer learning approaches.

The findings highlight three key contributions to professional development practice. First, the multi-tier and multi-component reward structures, operating at both individual and group levels, created comprehensive engagement pathways that balanced personal motivation with community-building incentives. Second, the strategic integration of technology, including a custom gamification platform and AI support tools, enabled efficient implementation across large cohorts, preserving meaningful human interaction while enhancing the overall learning experience. Third, resource-sharing mechanisms and group-level challenges promoted strategic collaboration, extending engagement beyond traditional course boundaries and fostering broader professional skills.

These results suggest that scaling professional development successfully depends on purposeful design aligned with learning objectives rather than technological sophistication alone. By prioritizing elements that support autonomy, competence, and relatedness, institutions can create meaningful and impactful learning experiences even with limited resources.

The findings point to implications beyond immediate training outcomes, suggesting how thoughtfully designed GTA development might contribute to broader educational practice. As universities seek to prepare teaching assistants for evolving educational roles, our experience offers practical approaches for navigating common challenges: balancing scale with impact, mandatory requirements with meaningful engagement, and institutional constraints with pedagogical innovation. While further research across different contexts would strengthen these insights, this case study provides a foundation for exploring how technology-enhanced design might support professional development at scale.

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Received December 31, 2024
Accepted June 20, 2025