Gamified Interface Design Enhances Student Engagement in Synchronous Video Conferencing Learning

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Abstract: - Synchronous video conferencing (VC) has become an established mode of higher education, but sustaining student engagement remains challenging, particularly in practice-oriented disciplines such as graphic design. This study examined the effects of three gamification mechanisms, including animated badges, experience points, and level upgrades, on behavioural, emotional, and cognitive engagement in synchronous VC learning. Guided by Self-Determination Theory (SDT), a quasi-experimental non-equivalent control group design was implemented with 124 first-year graphic design students from three public universities in China. Participants were distributed equally across a non-gamified control condition and three gamified conditions (n = 31 per group). Engagement was assessed before and after a four-week instructional intervention. Significant improvements were observed within the engagement components across all three gamified conditions, with no statistically significant change observed within the control condition. Participant-level total scores for each dimension of engagement were then used to estimate baseline-adjusted regression models. The models accounted for 97.4% of the variance in post-intervention behavioural engagement, 96.6% in emotional engagement, and 98.8% in cognitive engagement. Relative to the control condition and after controlling for baseline engagement, animated badges, experience points, and level upgrades were associated with increases of 40.35, 46.90, and 49.36 points in behavioural engagement; 48.82, 51.76, and 52.48 points in emotional engagement; and 95.86, 105.46, and 107.36 points in cognitive engagement, respectively. The results suggest that gamification mechanisms vary in the strength and direction of their relationship with engagement, with the strongest adjusted relationships being found between progression-based gamification and the cognitive dimension of engagement. The study extends the analysis beyond significance testing by introducing a quantitative, baseline-adjusted model to estimate post-intervention engagement given gamification condition and baseline engagement and offers a more precise basis for the design of gamified VC interfaces.

Key-Words: - Student Engagement, Video Conferencing, Synchronous Online Learning, Gamification Elements, Self-Determination Theory, Gamified User Interface Design, Cognitive Engagement.

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1 Introduction

Synchronous video conferencing (VC) has become commonplace in higher education due to the surge of online and hybrid curricula. VC platforms allow for live communication and teaching via Cisco Webex, Tencent Meeting, Zoom, Microsoft Teams and Google Meet. Despite these advantages, when it comes to sustaining student engagement, synchronous is not simply synchronous. Previous studies have found persistent issues such as lower participation rates, cognitive overload, "screen fatigue", distraction, and low social presence in online learning environments [1], [2], [3], [4], [5]. These challenges are still relevant in the context of the growing presence of both synchronous and hybrid teaching modalities in educational institutions.

In the context of practice-based disciplines like graphic design, which require iterative development, critical feedback, collaborative problem-solving, visual experimentation, and constant feedback, this becomes even more evident [6], [7], [8]. However, when these pedagogical processes are implemented in VC environments with no VC-specific instructional redesign, students may take a more passive role, engage in more passive learning behaviours and have weaker emotional connections with learning activities [9], [10], [11]. The pedagogical and interface design challenge, therefore, is to find out what design elements can keep the audience engaged during live online teaching.

A possible solution is gamification, which involves using specific elements of the game in other non-game situations to structure feedback, progression, and recognition [12], [13]. Previous studies showed that points, badges, levels and related feedback can have positive effects on participation, motivation, and persistence [14], [15]. But the majority of the empirical studies focused on asynchronous learning-management systems, mobile learning applications or self-paced learning [16], [17], [18], [19], [20]. In contrast, less focus has been placed on the different impacts that single gamification elements have in a synchronous VC learning setting.

This is a gap in theory and practice that is of significant value. Synchronous VC is a learning method that is distinct from asynchronous learning as it requires students to process information in real-time, be socially visible, interact with instructors and other students, and hold attention for long periods of screen-based learning. An effective asynchronous gamification mechanism might not yield a similar pattern of engagement during synchronous instruction. This present study aims to fill this gap, looking at three different mechanisms individually and quantifying their adjusted associations with post-intervention engagement.

1.1 Conceptualising Student Engagement in VC Learning

As presented in Figure 1, student engagement is commonly conceptualised as a multidimensional construct comprising behavioural, emotional and cognitive dimensions [21], [22], [23]. Behavioural engagement refers to the observable aspects of engagement in learning, such as participation, attention to learning, task completion, and interactions with instructors and peers [24]. In VC settings, behavioural engagement might be more susceptible to distraction, multitasking and reduced accountability [25], [26].

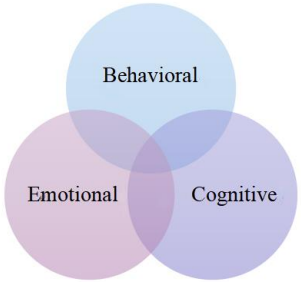


Fig. 1: Various dimensions of student engagement [21]
Source: created by the authors

Emotional engagement is the affective experience of learning, such as interest, enjoyment, perceived value, and pressure or tension [27], [28]. This is significant for creative disciplines where the student's willingness to explore ideas, to get feedback on the design, and to stick with a design process when confronted with challenges is linked to their affective experience of the learning environment.

Cognitive engagement involves the mental effort exerted and learning strategies used by learners, such as rehearsal, elaboration, organisation, critical thinking and metacognitive self-regulation [29], [30]. Synchronous VC can foster the superficial completion of the task under conditions of divided attention or high cognitive load [31], [32]. Thus, designs focusing on reflection, strategic effort, and self-regulation can be particularly relevant in this regard.

1.2 Gamification as a Motivational Learning Engagement

Gamification provides a structured way of incorporating motivational cues into learning activities [15], [33], [34], [35], [36], [37]. In the present study, three mechanisms, including animated badges, experience points, and level upgrades, were chosen, as they have distinct motivational functions.

Referring to Figure 2, animated badges are designed to serve as a visual means of recognition and achievement [18], [38], [39]. As demonstrated in the existing literature, animated badges can be employed to foster emotional engagement, recognise effort, create a sense of achievement and increase social visibility within a learning community [40], [41], [42]. Apart from this, animated badges also have the potential to be used in VC settings to help replace the lack of physical

cues and provide immediate, high-visibility feedback.



Fig. 2: This is an example of the types of badges (Achievement, Skill, Social, Participation, and Challenge) that help demonstrate different aspects of students' involvement within the gamified learning environment
Source: created by the authors

Experience points (Figure 3), in turn, are step-by-step measures that are built up in accordance with participation and task completion [38], [43], [44]. Reward systems are frequently associated with long-term behavioural engagement, and experience point systems are indeed a type of reward system [45], [46]. This gamified element could be used as a form of feedback to facilitate active participation and self-monitoring in synchronous VC environments.



Fig. 3: The graphic above illustrates how the experience points system works, with students gaining points for completing assignments and advancing through various stages
Source: created by the authors

Level upgrades are equivalent to mastery-based progression. Whilst discrete rewards can be given, levels offer a logical progression that allows students to progress when they are able to do more challenging tasks increasingly [47]. This can facilitate goal setting, strategic learning and self-regulation strategies, and level-based mechanics can be especially connected to cognitive engagement [48], [49]. Figure 4 illustrates the level-upgrade mechanism implemented in this study, demonstrating how students progress through multiple levels by completing assignments.

Taken together, these mechanisms represent recognition-based, progress-based and mastery-based forms of gamification. Analysing them in isolation would enable the study to transcend the homogeneous notion of 'gamification' as a single intervention and elucidate whether the various mechanisms are linked to various patterns of engagement for synchronous VC learning.



Fig. 4: This graphic showed the system level upgrades, with the progression through multiple stages and level up for assignment completion
Source: created by the authors

1.3 Theoretical Foundation: Self-Determination Theory

The basic theoretical foundation for understanding the mechanisms discussed in this study comes from a theory known as Self-Determination Theory (SDT). SDT proposes that sustained motivation and engagement are supported when the psychological needs for autonomy, competence and relatedness are adequately satisfied, as illustrated in Figure 5 [50].

In the current context, autonomy refers to how much control and volition learners feel in learning activities, competence refers to how effective and how well learners master the learning activities, and relatedness refers to how much connectedness learners feel with others [51], [52], [53]. Gamification can serve these needs by providing feedback, confirmation of progress, and social recognition, but it does not always have a positive impact on them and may depend on the way the mechanisms are designed and experienced [54], [55], [56], [57]. Therefore, it is important to have a mechanism-level analysis, especially in a synchronous VC environment in which immediacy and social interaction play a central role.

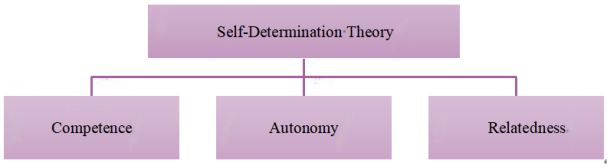


Fig. 5: Self-Determination Theory [50]
Source: created by the authors

1.4 Research Objective and Contribution

The main purpose of this study was to explore the relationships between the three individual gamification mechanisms (animated badges, experience points, and level upgrades) and behavioural, emotional and cognitive engagement in first-year graphic design education when learning takes place synchronously in a virtual classroom. This study focused on three related aims: (1) to analyse intragroup changes in engagement components, (2) to compare post-intervention engagement between conditions while controlling for baseline differences, and (3) to develop baseline-

adjusted predictive equations to quantify the relationships between each gamification mechanism and post-intervention engagement.

Four contributions are made in this study. Firstly, it contributes to the empirical gamification research by moving it to the field of synchronous VC learning in a higher-education graphic-design learning environment. Next, it breaks down the three gamification mechanisms instead of considering gamification as a homogeneous intervention. Third, it connects the observed patterns to SDT by considering recognition, progress and mastery as distinct motivational mechanisms. This study, from a quantitative perspective, takes a more extended approach to the traditional significance-testing paradigm by creating baseline-adjusted predictive models for engagement following intervention. Instead of using gamification as a category of interventions, the models treat animated badges, experience points, and level upgrades as separate parameters and estimate the adjusted associations of these with behavioural, emotional and cognitive engagement while controlling for baseline engagement. These equations offer a quantitative representation that is interpretable and can be used to represent the relationship between the baseline state of the learner, the gamification mechanism and the expected engagement after the intervention. The present research does not introduce a new mathematical estimation algorithm but offers an approach that is reproducible with software from a modelling perspective to compare gamification mechanisms and to create quantitative estimates of engagement within the observed research sample.

2 Methodology

2.1 Research Methods

2.1.1 Research Design Justification

This study employed a quasi-experimental non-equivalent control group design to examine the effects of three gamification mechanisms, including animated badges, experience points and level upgrades, on behavioural, emotional and cognitive engagement in synchronous VC learning. This method was selected because the participants were recruited from intact instructional classes, making individual randomisation impractical within the existing academic timetable. This design thus allows for comparison between intervention conditions, but assumes no baseline equivalency.

A total of 124 first-year graphic design students participated, with 31 students in each of four conditions. The non-gamified control group was assigned to the conventional synchronous VC instruction, whereas the three intervention groups were given the same instruction with one specific gamification mechanism. The same engagement instrument was administered before and after the intervention.

Since it was a non-equivalent experimental design, differences in the baseline were not assumed away but were explicitly examined. Behavioural and emotional engagement showed statistically significant baseline differences across conditions, whereas cognitive engagement did not. The baseline scores were thus included in the comparative and predictive analyses to minimise the effect of pre-existing group differences.

2.1.2 Procedure for Data Collection

Data collection was done in a structured 4-week timeline. The intervention procedure is summarised in Figure 6. The pre-intervention engagement measure was administered prior to the instructional intervention. Experimental groups received the same intervention content, while the control group received conventional synchronous VC classes. In the intervention period, the experimental groups received the same intervention content while the control group received conventional synchronous VC classes. The post-intervention measurement was then made with the same instrument. The design sought to hold instructional content, instructor and learning objectives constant while varying the presence and type of gamification.

The engagement instrument consisted of 70 Likert-type questions, with ratings ranging from 1 to 7. Behavioural engagement included 16 items in the four dimensions of Online Engagement (4), Online Active Learning (4), Online Teaching (5), and Online Academic Relevance (3). Emotional engagement consisted of 19 items, seven in Interest/Enjoyment, seven in Value/Usefulness, and five in Pressure/Tension. There were 35 items on cognitive engagement, which included Effort/Importance (5), Effort Regulation (4), Rehearsal (4), Elaboration (6), Organisation (4), Critical Thinking (5) and Metacognitive Self-Regulation (7). Responses for each item were combined within each dimension to result in dimension-level total scores for each participant. Total scores were divided by the number of items to obtain mean scores on the original 1-7 scale for descriptive presentation. The total scores for

participants were not rounded; these scores were used in statistical models.

2.1.3 Statistical Analysis

Descriptive statistics were calculated for pre-intervention and post-intervention behavioural, emotional, and cognitive engagement. The engagement instrument consisted of 70 items that were rated on a 7-point Likert scale, comprising 16 behavioural items, 19 emotional items, and 35 cognitive items. Participant-level dimension scores were computed as the sum of the items for each dimension, and mean scores were obtained for each dimension by dividing the dimension total by the number of items. Unrounded participant-level totals were retained for inferential analyses.

For each participant, item responses were aggregated to obtain dimension-level total scores. Behavioural engagement comprised 16 items, emotional engagement comprised 19 items, and cognitive engagement comprised 35 items. As each item was scored on a seven-point Likert scale, the possible total-score ranges were 16-112, 19-133 and 35-245, respectively. For descriptive reporting and interpretation, these total scores were transformed to mean scores by dividing the total on each dimension by the number of items in that dimension and keeping the original response metric of 1-7. The unrounded participant-level total scores were used for the inferential analyses, including baseline equivalence testing, ANCOVA and predictive regression models.

Pre-to-post changes within each experimental condition were examined at the component level using paired-samples t-tests. The analyses listed below relate to the detailed behavioural, emotional and cognitive components reported in Table 2, Table 3, Table 4 and Table 5.

One-way analysis of variance (ANOVA) on the participant level pre-intervention scores was conducted first to assess baseline equivalence. Since there were baseline differences between the four conditions in terms of behavioural and emotional engagement that were statistically significant, analysis of covariance (ANCOVA) was employed to assess post-intervention engagement when controlling for pre-intervention engagement. For cognitive engagement, the same baseline-adjusted ANCOVA approach was used to ensure the consistency of the comparison across all three dimensions. Experimental condition was specified as the fixed factor and the corresponding pre-intervention engagement score as the covariate. Prior to interpretation, the assumptions of linearity, homogeneity of regression slopes, independence of observations and homogeneity of residual variance were evaluated.

The ANCOVA models tested whether there was any difference between the four experimental conditions with regard to the post-intervention engagement scores, while controlling for the pre-intervention scores. The size of the adjusted experimental-condition effect was measured using partial eta squared (ηp^2). The differences between the gamification conditions and non-gamified control were interpreted using adjusted comparisons.

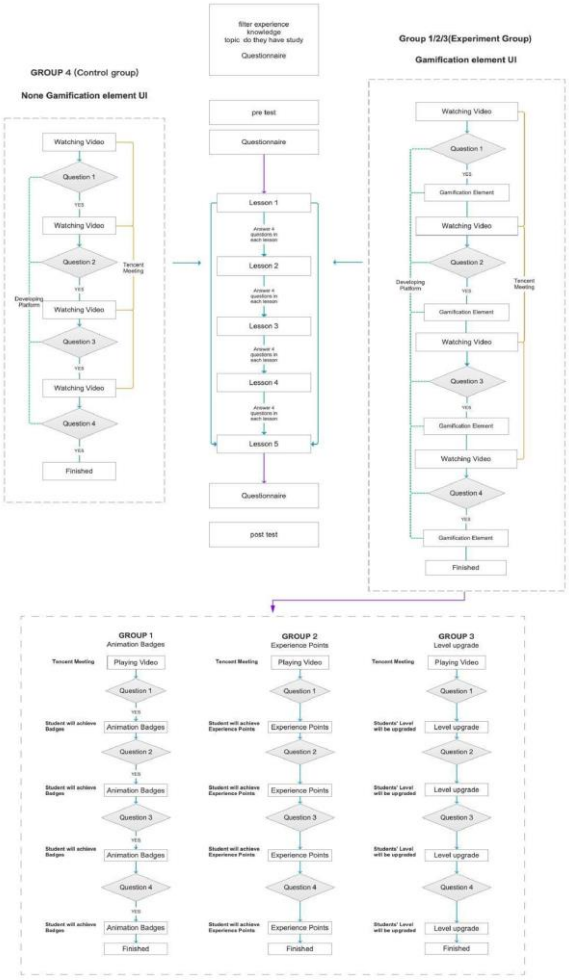


Fig. 6: Data Collection and Intervention Procedure
Source: created by the authors

As a complementary analysis, regression-based predictive models were developed to quantify the mechanism-specific association between gamification condition, baseline engagement, and post-intervention engagement. Dummy variables were used for animated badges, experience points and levelling. The control group was used as the reference group. The general specification for this was $Y_{post} = \beta_0 + \beta_1 Y_{pre} + \beta_2 AB + \beta_3 EP + \beta_4 LU + \varepsilon$. These coefficients offer a numerical approximation

of the adjusted difference that each gamification mechanism is associated with, and represent an understandable computational approximation of the engagement to be expected after the intervention.

2.2 Data Analysis

The statistical analysis was conducted using SPSS version 25 software. Categorical demographic variables were summarised using frequencies and percentages, and continuous variables using means and standard deviations. Internal consistency was assessed using Cronbach's alpha coefficients. Statistical significance was evaluated using two-sided tests at $\alpha = 0.05$. HC3 heteroscedasticity-robust standard errors were used for the regression coefficients.

The revised analysis emphasises the distinction between component-level within-group tests and dimension-level between-condition modelling. This enables to avoid the combination of multiple engagement components as a single homogeneous outcome whilst also offering a quantitative model directly answering the comparative and predictive question asked during the present analysis.

2.3 Ethical Considerations

This research received ethical approval from the Human Research Ethics Committee (HREC) of Universiti Malaysia Sarawak (UNIMAS) (IRB approval number: UNIMAS/TNC(PI)/09-65/02Jld.2(15)). Participation was voluntary and written informed consent was obtained from all students before data collection. Participants were informed that their responses would be treated confidentially and that they could withdraw without penalty. Data were coded to reduce the risk of participant identification and were stored securely.

3 Results

3.1 Participant Characteristics

The final sample consisted of 124 first-year undergraduate students in graphic design-related courses from three public universities in Zhejiang Province, China. A total of 31 students were used in each study condition. The sample included 83 women (66.9%) and 41 men (33.1%); 68 participants (54.8%) were aged 18 years and 56 (45.2%) were aged 19 years. All participants were from a single catchment area. The participants were distributed across Hangzhou City University (n = 42, 33.8%), Zhejiang University of Technology (n = 41, 33.1%) and Zhejiang Gongshang University (n = 41, 33.1%).

Because of the relatively small age span and focus within the same academic level, there was a lesser amount of variation due to year of study and previous exposure to higher education. The findings are, however, limited to the use of whole classes and the clustering of participants in three institutions, which means that the results cannot be generalised for other similar graphic-design groups.

Demographic data of the sample were summarised in Table 1.

Table 1. Demographic profile of participants (N = 124)

Demographic	Frequency (N)	Percentage (%)
Gender		
Female	83	66.9
Male	41	33.1
Age		
18	68	54.8
19	56	45.2
Marital Status		
Single	124	100
Married	0	0
Divorced	0	0
University		
Hangzhou City University	42	33.8
Zhejiang University of Technology	41	33.1
Zhejiang Gongshang University	41	33.1

Source: created by the authors

3.2 Effects of Gamification Interventions

3.2.1 Animated Badges

There was a statistically significant increase in all aspects of behavioural, emotional, and cognitive engagement after the animated-badge intervention in the component-level analyses (Figure 7, Figure 8 and Figure 9). As stated in Table 2, all four behavioural components included Online Engagement (OE), Online Active Learning (OAL), Online Teaching (OT) and Online Academic Relevance (OAR) showed significant pre-to-post improvements (all $p < 0.001$). These findings indicated that visual recognition cues were associated with greater participation, interaction and perceived relevance during synchronous VC learning.

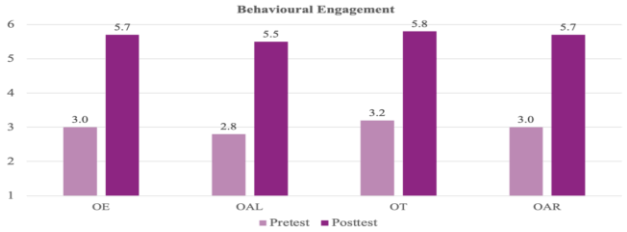


Fig. 7: Overall mean scores of behavioural engagement in different aspects before and after implementing animated badges
Source: created by the authors

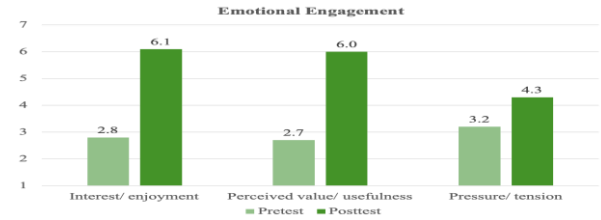


Fig. 8: Overall mean scores of emotional engagement in different aspects before and after implementing animated badges
Source: created by the authors

Also, animated badges were associated with significant increases in positive emotional engagement. Increased scores on both Interest/Enjoyment (+3.3 points, $p < 0.001$) and Value/Usefulness (+3.3 points, $p < 0.001$) were recorded on the 1-7 scale. On the other hand, Pressure/Tension had a slight change of about 1.1 points. This smaller change indicated that the pressure/tension component of the change was less related to the strongest emotional responses to animated badges, while the positive affect and perceived value were more related. The direction of the Pressure/Tension interpretation followed the scoring direction used for the instrument.

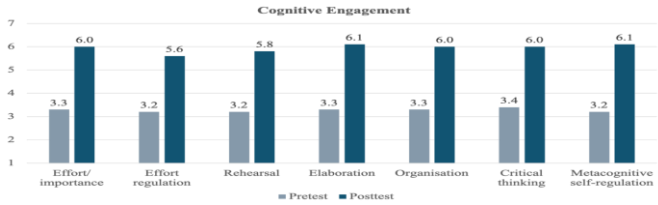


Fig. 9: Overall mean scores of cognitive engagement in different aspects before and after implementing animated badges
Source: created by the authors

The animated-badge intervention also resulted in a significant increase in cognitive engagement (Figure 9). Results at the component level indicated significant gains in rehearsal, elaboration, organisation and metacognitive self-regulation, with all component tests attaining $p < 0.001$. The findings indicated that recognition-oriented feedback is not restricted to the affective dimension but is also correlated with higher investment in learning strategies as reported.

Table 2. Paired t-test results demonstrating the significant impact of animated badges on behavioural, emotional, and cognitive engagement

Dimension	Mean Difference ($\bar{d}$)	t-value	p-value
Behavioural Engagement			
Online Engagement	2.7	15.00	< 0.001
Online Active Learning	2.7	15.00	< 0.001
Online Teaching	2.6	14.44	< 0.001
Online Academic Relevance	2.7	15.00	< 0.001
Emotional Engagement			
Interest/Enjoyment	3.3	18.33	< 0.001
Value/Usefulness	3.3	18.33	< 0.001
Pressure/Tension	2.6	14.44	< 0.001
Cognitive Engagement			
Effort/Importance	2.7	15.00	< 0.001
Effort Regulation	2.4	13.33	< 0.001
Rehearsal	2.6	14.44	< 0.001
Elaboration	2.8	15.56	< 0.001
Organisation	2.7	15.0	< 0.001
Critical Thinking	2.6	14.44	< 0.001
Metacognitive Self-Regulation	2.9	16.11	< 0.001

Source: created by the authors

3.2.2 Experience Points

The experience-points condition resulted in significant improvements on all behavioural components (Figure 10, Figure 11 and Figure 12), with means of about 3.4 points for OE, 3.3 points for OAL, and 2.9 points for OT and OAR (all $p < 0.001$). This is consistent with the idea of experience points as continuous progress feedback that makes participation and task completion visible as continuous progress.

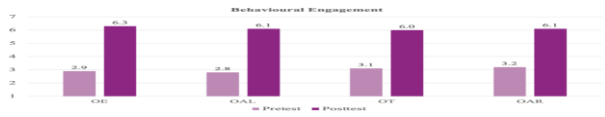


Fig. 10: Overall mean scores of behavioural engagement in different aspects before and after implementing experience points
Source: created by the authors

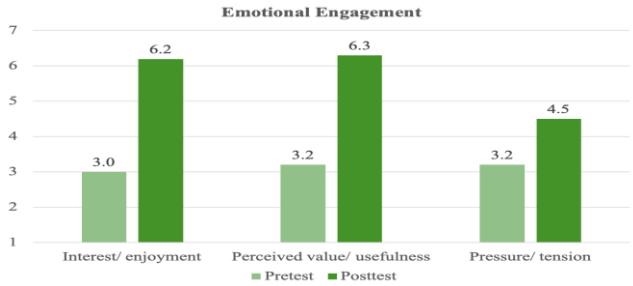


Fig. 11: Overall mean scores of emotional engagement in different aspects before and after implementing experience points
Source: created by the authors

Emotional engagement was also correlated with significant improvement from experience points. Interest/Enjoyment increased by approximately 3.2 points and Value/Usefulness by approximately 3.1 points (both $p < 0.001$), while Pressure/Tension showed a smaller increase of approximately 1.3 points. The trend suggested that more positive affect and perceived value were linked to continuous progress feedback, while the increase in pressure/tension was a bit less.

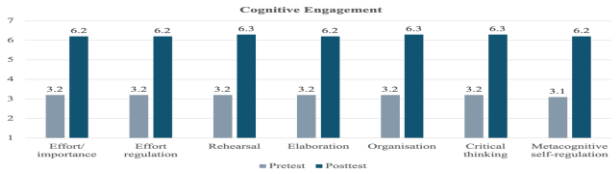


Fig. 12: Overall mean scores of cognitive engagement in different aspects before and after implementing experience points
Source: created by the authors

For cognitive engagement, significant and relatively consistent gains were found for all seven components (all $p < 0.001$); the mean gain for each component was about 3.0 to 3.1 points (Table 3). These changes, however, were repeated consistently, indicating that experience points were not only related to participation, but also to persistent attempts and the deliberate application of cognitive strategies.

Table 3. Paired t-test results demonstrating the significant impact of experience points on behavioural, emotional, and cognitive engagement

Dimension	Mean Difference ($\bar{d}$)	t-value	p-value
Behavioural Engagement			
Online Engagement	3.4	17.17	< 0.001
Online Active Learning	3.3	18.33	< 0.001
Online Teaching	2.9	16.11	< 0.001
Online Academic Relevance	2.9	16.11	< 0.001
Emotional Engagement			
Interest/Enjoyment	3.2	19.75	< 0.001
Value/Usefulness	3.1	19.14	< 0.001
Pressure/Tension	1.3	7.22	< 0.001
Cognitive Engagement			
Effort/Importance	3.0	16.67	< 0.001
Effort Regulation	3.0	16.67	< 0.001
Rehearsal	3.1	17.22	< 0.001
Elaboration	3.0	16.67	< 0.001
Organisation	3.1	17.22	< 0.001
Critical Thinking	3.1	15.66	< 0.001
Metacognitive Self-Regulation	3.1	15.66	< 0.001

Source: created by the authors

3.2.3 Level Upgrades

For the level upgrade condition, the mean changes for all behavioural components were also quite large, ranging from 2.9 to 3.2 points (all $p < 0.001$), as illustrated in Table 4 and Figure 13, Figure 14 and Figure 15. Results showed that there was a significant relationship between the use of structured progression and participation, interaction and perceived academic relevance.

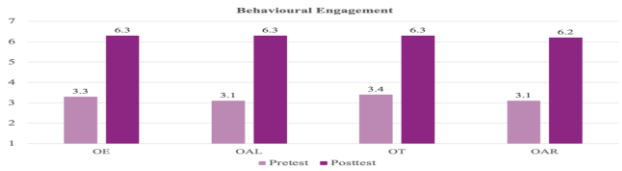


Fig. 13: Overall mean scores of behavioural engagement in different aspects before and after implementing level upgrades
Source: created by the authors

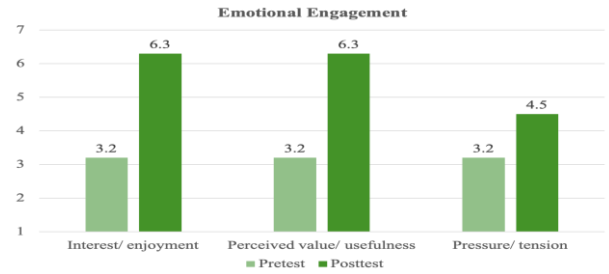


Fig. 14: Overall mean scores of emotional engagement in different aspects before and after implementing level upgrades
Source: created by the authors

The level-upgrade condition showed a significantly greater increase in emotional involvement. For both Interest/Enjoyment and Value/Usefulness, there was an increase of about 3.1 points ($p<0.001$), and the change for

Pressure/Tension was smaller. The pattern supports the development of a progression system that gives evidence of mastery that is observable and can enhance perceived competence.

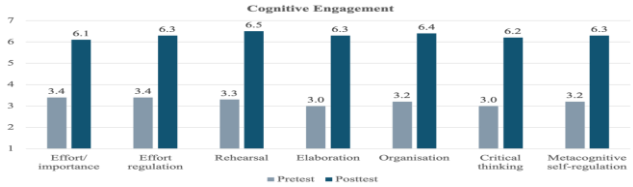


Fig. 15: Overall mean scores of cognitive engagement in different aspects before and after implementing level upgrades
Source: created by the authors

Cognitive engagement showed the greatest level upgrade gains in the component-level analysis. Elaboration, Rehearsal, Critical Thinking, Organisation and Metacognitive Self-Regulation all showed large and statistically significant improvements ($p < 0.001$). These results are consistent with the interpretation that structured progression may be particularly relevant to mastery-oriented learning behaviours.

Table 4. Paired t-test results demonstrating the significant impact of experience points on behavioural, emotional, and cognitive engagement

Dimension	Mean Difference ($\bar{d}$)	t-value	p-value
Behavioural Engagement			
Online Engagement	3.0	16.67	< 0.001
Online Active Learning	3.2	17.78	< 0.001
Online Teaching	2.9	16.11	< 0.001
Online Academic Relevance	3.1	17.22	< 0.001
Emotional Engagement			
Interest/Enjoyment	3.1	19.14	< 0.001
Value/Usefulness	3.1	19.14	< 0.001
Pressure/Tension	1.3	7.22	< 0.001
Cognitive Engagement			
Effort/Importance	2.7	13.64	< 0.001
Effort Regulation	2.9	16.11	< 0.001
Rehearsal	3.2	17.78	< 0.001
Elaboration	3.3	20.37	< 0.001
Organisation	3.2	17.78	< 0.001
Critical Thinking	3.2	16.16	< 0.001
Metacognitive Self-Regulation	3.1	19.14	< 0.001

Source: created by the authors

3.2.4 Control Group

The non-gamified control group showed little change across the engagement components (Figure 16, Figure 17, Figure 18). The behavioural components resulted in small non-significant changes; the emotional components also experienced no statistically significant benefits. Cognitive components were similarly stable, with the exception of the small change reported for Effort/Importance ($p = 0.044$). In summary, the control condition did not show the wide range of improvement found across the three gamified conditions.

The mean scores in the emotional involvement subscale did not change significantly from pretest to posttest for the control group. The difference in means between the gamified and the non-gamified VC environment for the Interest/enjoyment scale (0.0- 0.2) and the Perceived value/usefulness scale (0.0-0.2) was very small and not statistically significant ($p > 0.05$), which suggested that the non-gamified VC environment did not generate any positive affective responses or reinforce students' emotional relationship with the learning activities (Table 5). Furthermore, pressure and tension levels were also not meaningfully reduced, suggesting that affective strain typically found in synchronous online learning did not seem to be reduced through traditional VC instruction.

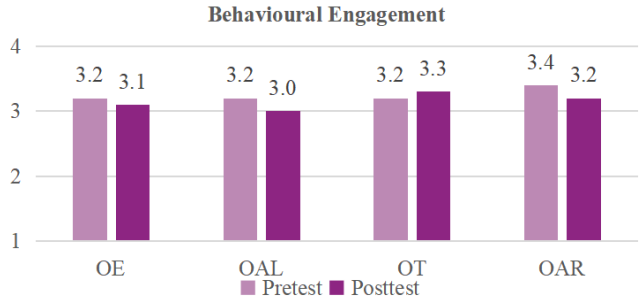


Fig. 16: Overall mean scores of behavioural engagement in different aspects in the non-gamified environment (pretest and posttest)
Source: created by the authors

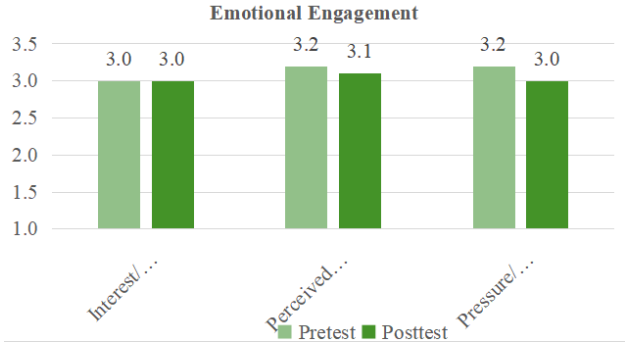


Fig. 17: Overall mean scores of emotional engagement in different aspects in the non-gamified environment (pretest and posttest)

Source: created by the authors

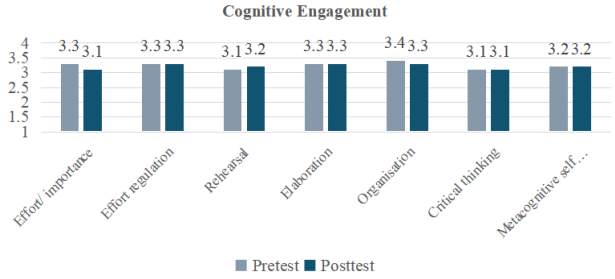


Fig. 18: Overall mean scores of cognitive engagement in different aspects in the non-gamified environment (pretest and posttest)
Source: created by the authors

The component-level results therefore indicate a clear within-condition distinction: gamified conditions showed broad and statistically significant increases, whereas the non-gamified condition remained comparatively stable. These within-condition results, however, do not by themselves establish which gamification mechanism was associated with the strongest post-intervention outcome. That question is addressed using baseline-adjusted comparative models below.

Table 5. Paired t-test results demonstrating the engagement states in the non-gamified environment

Dimension	Mean Difference ($\bar{d}$)	t-value	p-value
Behavioural Engagement			
Online Engagement	0.1	0.53	0.601
Online Active Learning	0.2	1.33	0.192
Online Teaching	0.1	0.85	0.205
Online Academic Relevance	0.2	0.69	0.496
Emotional Engagement			
Interest/Enjoyment	0.0	0.39	0.702
Value/Usefulness	0.1	1.75	0.090
Pressure/Tension	0.2	1.18	0.246
Cognitive Engagement			
Effort/Importance	0.2	2.10	0.044
Effort Regulation	0.0	0.13	0.895
Rehearsal	0.2	0.62	0.541
Elaboration	0.0	0.05	0.958
Organisation	0.1	0.92	0.364
Critical Thinking	0.0	0.42	0.677
Metacognitive Self-Regulation	0.0	0.80	0.428

Source: created by the authors

3.3 Baseline-Adjusted Comparative Effects

Baseline equivalence was examined using one-way ANOVA on the participant-level pre-intervention dimension totals. There were significant differences between the four conditions for behavioural engagement, $F(3, 120) = 6.31$, $p < 0.001$, and emotional engagement, $F(3, 120) = 11.09$, $p < 0.001$. No significant difference was found between the groups at baseline on cognitive engagement, $F(3, 120) = 1.27$, $p = 0.288$. These results supported the importance of adjusting for baseline engagement in addition to making an unadjusted post-intervention comparison.

Post-intervention engagement was thus analysed using ANCOVA with the pre-intervention score as the covariate and experimental condition as the fixed factor. As shown in Table 6, the adjusted analyses indicated statistically significant differences among the four conditions for behavioural, emotional, and cognitive engagement, with the experimental-condition effect significant for behavioural engagement, $F(3, 119)$, $p < .001$; emotional engagement, $F(3, 119)$, $p < 0.001$; and cognitive engagement, $F(3, 119)$, $p < 0.001$. The adjusted effects were interpreted in conjunction with the mechanism-specific regression coefficients below.

Table 6. Baseline equivalence and baseline-adjusted predictive model fit

Engagement Dimension	Baseline F(3, 120)	Baseline p-value	ANCOVA effect	ANCOVA p-value	Interpretation
Behavioural	6.31	< 0.01	F(3, 119)	0.974	Significant adjusted condition effect
Emotional	11.09	< 0.01		0.966	Significant adjusted condition effect
Cognitive	1.27	0.288		0.988	Significant adjusted condition effect

Source: created by the authors

3.4 Mechanism-Specific Predictive Regression Models

To get a quantitative view of the relationship between gamification mechanisms and engagement, three baseline adjusted predictive models were estimated based on the participant-level engagement totals. Both models assume that a baseline level of engagement is the starting point for learning and that the gamification condition is a parameter of the mechanism. This formulation constitutes an

interpretable computational model of what is expected to happen to engagement for the observed population after intervention.

For instance, when looking at the animated-badge coefficient and keeping baseline behavioural engagement constant, the coefficient of behaviour-wise total score is about 40.35 points higher than that of the non-gamified control condition. This is equivalent to about 2.52 points on the original 1–7 scale, as there are 16 items in behavioural engagement. The adjusted associations with experience points and level upgrades are about 2.93 and 3.08 points, respectively. The same conversion can be applied to the emotional and cognitive models using 19 and 35 items, respectively.

The estimated predictive equations were:

Behavioural: $B_{post} = 50.134 + 0.009(B_{pre}) + 40.353(AB) + 46.902(EP) + 49.356(LU)$.

Emotional: $E_{post} = 43.460 + 0.246(E_{pre}) + 48.820(AB) + 51.756(EP) + 52.478(LU)$.

Cognitive: $C_{post} = 93.516 + 0.166(C_{pre}) + 95.860(AB) + 105.465(EP) + 107.358(LU)$.

Model adequacy was considered using coefficient significance, R^2, adjusted R^2, residual diagnostics and multicollinearity assessment (Table 7). The R^2 values reported are estimates from the sample and are not externally validated and therefore do not show predictive accuracy. Equations should thus be viewed as sample-specific prediction functions that need to be validated in other samples before use.

The behavioural model explained 97.4% of the variance in post-intervention behavioural engagement ($R^2 = 0.974$; adjusted $R^2 = 0.973$; $F(4,119) = 721.12$, $p < 0.001$). The emotional model explained 96.6% ($R^2 = 0.966$; adjusted $R^2 = 0.965$; $F(4,119) = 518.50$, $p < 0.001$), and the cognitive model explained 98.8% ($R^2 = 0.988$; adjusted $R^2 = 0.988$; $F(4,119) = 1808.70$, $p < 0.001$).

All three gamification coefficients had positive and significant values for the present study compared to the control condition ($p < 0.001$). The coefficients for behavioural engagement were 40.35 (animated badges), 46.90 (experience points) and 49.36 (level upgrades). The coefficients for emotional engagement were 48.82, 51.76 and 52.48. For cognitive engagement, they were 95.86, 105.46 and 107.36. There were significant pairwise differences with experience points and level upgrades for behavioural engagement (difference = 2.45 total-score points, $p = 0.006$), but not for emotional engagement (difference = 0.72, $p = 0.501$) and cognitive engagement (difference = 1.89, $p = 0.136$). The coefficients are thus to be interpreted as moderated associations, not to be interpreted as generally causal treatment effects.

These equations can then serve as a quantitative representation of the relationship between baseline engagement, gamification condition and expected post-intervention engagement. They should not be seen as prediction rules that are universally applicable, but rather as sample-based adjusted prediction functions.

Table 7. Baseline-adjusted regression models predicting post-intervention engagement

Outcome	Intercept B (SE)	Baseline B (SE)	Animated badges B (SE)	Experience points B (SE)	Level upgrades B (SE)	R^2	Adjusted R^2
Behavioural	50.134 (3.891)	0.009 (0.072)	40.353 (1.007)	46.902 (1.073)	49.356 (0.957)	0.974	0.973
Emotional	43.460 (7.470)	0.246 (0.119)	48.820 (1.528)	51.756 (1.324)	52.478 (1.210)	0.966	0.965
Cognitive	93.516 (10.958)	0.166 (0.092)	95.860 (1.383)	105.465 (1.686)	107.358 (1.462)	0.988	0.988

Note: B = unstandardized regression coefficient; SE = HC3 robust standard error. The control condition is the reference category. All gamification-condition coefficients were $p < 0.001$. Baseline engagement was significant for emotional engagement ($p = 0.039$) but not behavioural ($p = 0.904$) or cognitive engagement ($p = 0.072$).

Source: created by the authors

4 Discussion

These results give two pieces of complementary evidence. Firstly, the paired-samples analyses conducted at the component level reveal significant within-condition gains in behaviour, emotion, and cognition engagement in both the gamified conditions, with the control condition being comparatively stable. Second, the baseline-adjusted ANCOVA models show that differences among the experimental conditions remained statistically significant after accounting for initial engagement. The subsequent regression analysis provides mechanism-specific coefficients that quantify the adjusted association of each gamification condition

relative to the non-gamified control. This analytical sequence allows for the distinction of within-group change from between-condition change adjusted for the engagement post-intervention, and offers a quantitative approach for estimating post-intervention engagement from engagement baseline and gamification condition.

The regression analysis results are the main quantitative aspect of the revision. Experience points were most strongly associated with behavioural engagement (46.90 total-score points), followed by level upgrades (49.36), and animated badges (40.35); the ordering suggests that behaviour-enhancing mechanisms were strong predictors of behavioural engagement compared to recognition alone. For emotional engagement, the adjusted coefficients were 48.82 for animated badges, 51.76 for experience points and 52.48 for level upgrades. The difference between experience points and level upgrades, however, was not statistically significant ($p = 0.501$), meaning both systems should be looked upon as generally similar for emotional involvement instead of a winner being decided. Level upgrades (107.36), experience points (105.46), and badges (animated) (95.86) had the highest coefficients in terms of cognitive engagement. The difference between the level-upgrade coefficient and the experience-points coefficient was not statistically significant ($p = 0.136$), although the former was numerically larger. It therefore appears to be the strongest defensible conclusion that progression-based mechanisms were linked with the greatest cognitive benefits, and experience points and level increases were statistically equivalent.

The adjusted coefficients can also be expressed on the original 1-7 mean scale by dividing the dimension-level effects by the number of items. Relative to the control condition, the estimated associations were approximately +2.52, +2.93 and +3.08 points for behavioural engagement under animated badges, experience points and level upgrades, respectively; +2.57, +2.72 and +2.76 points for emotional engagement; and +2.74, +3.01 and +3.07 points for cognitive engagement. These estimates offer a practical interpretation of the regression model: With no baseline engagement score, the chosen gamification mechanism was correlated with a significant change in the engagement score expected after the intervention, on the original engagement scale.

The very high R^2 values should nevertheless be interpreted in the context of the study design. They signify a good explanatory fit in this sample and do not provide evidence of how well the models will perform in other institutions, disciplines or learner populations. The models were estimated from 124 participants from three universities and from a single four-week intervention. External validation with an independent sample is therefore required before the equations are used as general prediction tools.

4.1 Behavioural Engagement and Progress Feedback

Findings at the component level revealed widespread enhancements of behavioural engagement across all three gamification mechanisms. This introduces a crucial difference in the results of the adjusted regression: sizeable behavioural benefits were observed for experience points and level increases, whereas only minor benefits were seen for animated badges. The progression mechanisms are in line with the concept of continuous feedback and a sense of progress that the learners are getting, motivating them to keep on involving in the task and the learning process [58], [59]. Animated badges, on the other hand, offer recognition at certain achievement milestones and can possibly be more efficient at rewarding specific accomplishments than at maintaining ongoing engagement.

This control condition, without the inclusion of gamification, is stable and offers a helpful contrast. The study also cannot exclude all other explanations because the study did not randomise participants individually; however, the absence of other comparable gains within conditions and the large gains as a function of conditions after adjustment for other factors suggests that meaningful differences in engagement during the intervention period may have been associated with the gamified instructional designs.

4.2 Emotional Engagement and Recognition

An increase in emotional engagement was found in all three gamified conditions, and especially in Interest/Enjoyment and Value/Usefulness. The animated badges displayed a high positive-affect trend, aligning with the visual recognition mechanism of conveying achievements and making progress salient [39], [60]. A smaller difference in the Pressure/Tension component suggests that gamification should not be read as decreasing all negative emotions. Instead, the most consistent emotional pattern was related to increased interest, enjoyment and perceived value.

These regression results confirm this interpretation. Although level upgrades had the largest numerical coefficient for emotional

engagement, the difference between level upgrades and experience points was not statistically significant. The evidence therefore supports the use of multiple mechanisms for emotional engagement, but doesn't support the claim that one progression mechanism is better than the other.

4.3 Cognitive Engagement and Mastery-Oriented Progression

The greatest absolute increases were observed for cognitive engagement, especially in elaboration, rehearsal, critical thinking, organisation and metacognitive self-regulation. Similarly, the larger coefficients were obtained for experience points and level upgrades in the adjusted regression models. These mechanisms can offer constant or milestone feedback on progress, which can help with effort regulation, goal setting, and strategic learning [61], [62], [63], [64]. The results are therefore also in line with the idea that progression-based gamification might be particularly useful in the context of the desired result being continuous cognitive engagement rather than immediate recognition.

However, the difference in the cognitive regression coefficient between experience points and level upgrades was not statistically significant. Based on the current evidence, the current conclusions are that gamification can be used as a general design direction, and that progression-based gamification is not necessarily superior to level-based gamification.

4.4 Interpretation Through the Lens of Self-Determination Theory

The observed patterns can be interpreted through SDT, although the present study did not directly measure autonomy, competence or relatedness. Animated badges provide visible recognition and may strengthen perceived competence; experience points provide continuous information about progress; and level upgrades provide structured mastery goals. These features can plausibly support competence, and the synchronous learning context would provide opportunities for relatedness; these features can plausibly support competence, and the synchronous learning context would provide opportunities for relatedness. These interpretations should, however, be understood as theoretical explanations rather than as direct tests of SDT mechanisms since psychological needs were not assessed.

4.5 Contribution to the Literature and Implications for Interface Design

It is important to note the three major contributions made by the study to the literature. First, it distinguishes three gamification mechanisms (used in a synchronous VC environment) from aggregating gamification into a single composite intervention. Second, it examines engagement across behavioural, emotional and cognitive dimensions, allowing the mechanisms to be interpreted according to the type of engagement they are most strongly associated with. Third, the baseline-adjusted regression equations measure the predicted engagement after intervention that is attributable to each mechanism, meaning that they control for baseline engagement. This last contribution takes the investigation beyond the traditional model of a significance test.

The findings offer guidance for instructional designers to choose gamification based on the aim of engagement. Badges that are recognition-oriented might be suitable when there is a focus on recognition of achievement and positive affect. Experience points could be valuable where the need for ongoing feedback and involvement is paramount. An improvement in level upgrades might especially be appropriate if the learning design focuses on mastery, strategic effort and deeper cognitive processing. The following recommendations are to be used as design hypotheses to be tested with other groups of learners, not as general rules.

Another suggestion is that the elements of gamification should be embedded into the learning process and not used as mere surface decoration of the learning interface. They seem to be more dependent on the feedback, progression and achievement information they provide learners. It may, therefore, be worth considering combining mechanisms, but this study has not investigated combinations and cannot determine whether a multi-mechanism design would be more effective than the individual mechanisms.

There are a total of 70 items in 14 component scales in the engagement instrument. In the present sample, an independent confirmatory factor analysis was not performed, although internal consistency was determined. A full item CFA would need a much larger sample than the number of indicators to get reliable estimates of the parameters. Large independent samples should be used to replicate the measurement structure, and measurement invariance across institutions, disciplines and learners should be checked prior to generalisations.

Future research may involve using a structural equation modelling (SEM) approach to investigate the mediation between gamification and cognitive engagement through changes in emotional engagement. This kind of mediation model was not estimated in the present study, since the research design was based on comparing individual gamification mechanisms and the sample size was small (N = 124), thus making it less suited to a high-dimensional latent variable mediation model that includes the full measurement structure. The mediation pathway is thus a tentative hypothesis for future studies.

In the present study, engagement data were only gathered at two points: prior to the intervention and at the end of the four-week intervention. The study, therefore, cannot quantify an engagement trajectory over the four weeks and cannot directly test if the engagement demonstrated in the study was sustained, grew or waned over time. To model temporal trajectories and potential novelty effects, a repeated measures design with multiple assessments over time during the intervention would be needed. This restriction would have to be taken into account when evaluating the long-lasting nature of observed effects.

Mathematical and computer scope. The present study presents the development of baseline-adjusted statistical prediction functions, not a new mathematical optimisation algorithm or a dynamic systems model. This distinction is made on purpose since there are 2 measurement time points and 4 experimental conditions. More sophisticated computational modelling analysis, such as the use of longitudinal engagement dynamics, optimisation of gamification sequences and combinations, and latent-variable mediation, would call for richer experimental data. Future studies could provide repeated engagement measurements across an intervention and alter gamification intensity, sequence and combinations, which would allow for the empirical foundations of dynamic and optimisation models.

4.6 Limitations and Future Research

There are several limitations to be noted. First, by having a quasi-experimental non-equivalent design, this design does not achieve the same level of causal certainty as individual randomisation. Intact classes might have unmeasured differences, and although baseline scores were used in the comparative models, the results may not represent the true differences between classes. Secondly, because of the small sample size of 124 first-year graphic design students from three universities in one region of China, it is difficult to generalise the findings to other situations. Thirdly, it is not clear whether engagement gains observed during the intervention will remain after 4 weeks of instruction, as future evaluations will be needed to determine this. Fourthly, the regression models were internally estimated from the same sample and have not undergone external validation. Fifth, SDT need satisfaction was not directly measured in the study, and the proposed mechanisms of autonomy, competence and relatedness are only theoretically interpreted and not tested. Future studies should employ more extensive and more varied samples, a longer follow-up time, a direct measure of SDT need satisfaction, and combinations or sequences of gamification mechanisms. The proposed equations would also have to be externally validated before they can be used as operational predictions.

4.7 Overall Interpretation

Overall, the evidence is in favour of a differentiated perspective on gamification in synchronous VC learning. Each of the three mechanisms yielded large engagement gains, with the adjusted patterns not being the same. There were strong associations between recognition-oriented badges and emotional engagement, with progression-oriented mechanisms having the largest adjusted associations with behavioural and cognitive engagement. The regression framework provides a quantitative basis for expressing these differences while avoiding the assumption that all forms of gamification produce the same outcome.

5 Conclusion

This study revealed three gamification mechanisms, including animated badges, experience points and level upgrades, in synchronous VC learning among first-year graphic design students. The component-level analyses revealed general and statistically significant improvements in the gamified conditions, while the comparatively stable non-gamified control condition failed to improve. Baseline-adjusted models also indicated that the experimental condition was strongly related to post-intervention behavioural, emotional and cognitive engagement, controlling for baseline engagement.

The primary quantitative contribution was the set of baseline-adjusting regression equations that established a baseline and showed the relationship between the baseline level of engagement and the post-intervention levels of engagement while also accounting for the gamification condition. The

models accounted for 97.4%, 96.6% and 98.8% of the variance in behavioural, emotional and cognitive engagement, respectively. These values demonstrated strong within-sample model fit, while the limitations of the quasi-experimental design and the absence of external validation require cautious interpretation.

From a design perspective, the findings suggest that gamification should be selected according to the intended engagement outcome. Animated badges might be especially helpful for recognition and positive affect, whereas experience points and level-ups might have more of an effect on sustained behavioural and cognitive engagement. The results support an SDT-based understanding of gamification, but tests of autonomy, competence and relatedness should be included in future studies.

In summary, the study provides empirical and quantitative evidence that individual gamification mechanisms can be differentiated by their association with engagement outcomes in synchronous VC learning. The suggested regression framework provides a more solid ground to compare mechanisms and serves as a basis for further validation and refinement in other learning areas.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the author(s) utilized artificial intelligence (AI) technologies solely for the purpose of linguistic refinement and grammatical correction. Following the application of these tools, the author(s) comprehensively reviewed, verified, and edited the resulting text. The author(s) maintain full accountability and responsibility for the accuracy, integrity, and final content of the publication.

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Ethics Approval

This study was approved by the Human Research Ethics Committee (HREC), Universiti Malaysia Sarawak (UNIMAS) *(IRB approval number: UNIMAS/TNC(PI)/09-65/02Jld.2(15))*. This study was conducted in accordance with the ethical principles outlined in the *Declaration of Helsinki* and the ethical guidelines for research involving human participants established by Universiti Malaysia Sarawak (UNIMAS).

Conflict of Interest

The authors have no conflicts of interest to declare.

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