A Dual-Role Gamified Framework for Peer Code Review in Classroom Settings

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ABSTRACT

Peer Code Review (PCR) is a proven pedagogical method for improving programming skills and collaboration. However, most gamified PCR systems emphasise reviewers while giving limited recognition to authors. This paper presents CODUAL, a conceptual dual-role gamified PCR framework that applies points, leaderboards, and badges for both roles. Using Likert-scale ratings and alignment-based rewards, CODUAL promotes balanced engagement and sustained effort. Grounded in Self-Determination Theory (SDT), it supports autonomy, competence, and relatedness to strengthen motivation. Future empirical evaluation, planned with undergraduate programming students at University Technical Malaysia Melaka (UTeM), will compare CODUAL with a non-gamified PCR platform using the Technology Acceptance Model (TAM) and BPNSFS.

Keywords: Peer code review, gamification, peer learning, self-determination theory, programming course

INTRODUCTION

Code review is a crucial activity in the software engineering industry that fosters collaborative environments which require developers to give feedback from each other's code with the aims to look for defects and ensure only high-quality codes are applied into the final version of the software[1]. This activity not only enhancing the software quality but also minimizes the time and effort required for corrections specifically during the maintenance phase. In educational settings, particularly within computer science courses, Peer Code Review (PCR) is implemented to replicate industry code review practices, requiring students to provide constructive feedback on each other's code [2].

By incorporating PCR as a classroom assessment, educators can bridge the gap between classroom environment and the software industry as it closely mirrors professional code review practices. This approach not only familiarizes students with real-world software development processes but also provides them with valuable hands-on experience in code review context [3]. Its implementation in education has demonstrated promising outcomes, such as enhancing programming skills through the completion of assigned programming tasks, fostering critical thinking through the code review process[4] and improving collaborative skills due to its engaging in peer-to-peer interactions.

Despite educational PCR has potential as an effective strategy for promoting code review among students, its execution in the classroom may fail due to a lack of student engagement [5], [6] that leads to low-quality reviews [7], [8]. Low student engagement often arises from students perceiving the task as merely another assessment requirement which leading them to invest minimal effort in the review process [9], [10]. Thus, to mitigate engagement issues, a gamification approach needs to be incorporated to enhance student engagement level throughout the PCR execution. Gamification is a process of enhancing engagement by applying game design in

a non-game environment. Elements such as points, badges, levels and feedback has effectively stimulated student motivation and engagement specifically through e-learning in higher education [11], [12]. Even in the context of educational PCR, the incorporation of gamification has been introduced to a number of studies but still minimally applied which can be seen as room for more improvement.

As stated by Saxena & Mishra [13], it is imperative to design effective classroom activities that corresponds to self-determination theory (SDT) which can provide more meaningful engagement with the Generation Z preferred learning style. To bridge the gap between conventional gamification and deeper motivational design, this study presents a dual-role based gamified educational PCR framework called Collaborative Dual Role (CODUAL) that is grounded in SDT. CODUAL is a unique gamified educational PCR framework that introduces dual leaderboards which consists authors and reviewers whereby the student can have achievement either in one of the roles or both. By integrating the dual role gamification approach due to its support on autonomous learning, CODUAL contributes a novel direction for motivating student participation in educational PCR. Thus, this paper presents the design, theoretical foundations, and expected outcomes of the CODUAL framework, with its empirical validation to be conducted in a future study involving undergraduate Programming Technique students at UTeM. To guide the development of this framework, the following are the research questions (RQs):

1. How can the CODUAL framework be designed incorporating SDT to support the motivational needs and preferred learning styles of Generation Z students for PCR?
2. What are the gamification components of the CODUAL framework and how do they address both roles of author and reviewer motivation that fits with SDT?

The remainder of this paper is organized as follows. The second section highlights the related works of the existing gamification-based PCR frameworks and its gap. The third section discussed the methodology of the proposed framework from its theoretical foundation's application to its conceptual framework development. The fourth section provide details of the results and findings in pertaining how the experiment is going to be conducted for future study. Lastly, the final section concludes this study by summarizing the key discussions and outlining directions for future empirical implementation and evaluation.

Related Work

In many studies, gamification is presented as a successful instrument for improving learning in programming courses. For instance, the work by Azmi et al.[14] map badges, progress bars, and leaderboards onto the Community of Inquiry (COI) to strengthen social, cognitive, and teaching presence targeting disengagement and clarifying how specific mechanics drive participation. While, khaleel et al.[15] propose a gamification-based learning framework that aligns points, badges, leaderboards, stages/levels, and real-time dashboards with programming learning requirements; their expert–student evaluation reports strong acceptance (mean ratings > 4.0) for these element–requirement pairings. Collectively, these results suggest that structured rubrics plus visibility mechanics can be repurposed for PCR.

Over the past years, only a minimal number of studies have explored gamification in educational PCR, with most research focusing on limited aspects of the review process. Among the notable contributions, Indriasari et al. have conducted multiple studies on gamified PCR frameworks. In one study, Indriasari et al. [7], proposed a gamification approach that awarded students based on the length of comments and peer ratings in a web-based tool. The longer the comments provided by a student, the higher the points awarded. In addition to the points system, the study incorporated a leaderboard based on cumulative points and awarded badges to highly rated reviews. The evaluation was conducted using an experimental design, comparing a gamified group with a non-gamified control group, and the findings showed that students in the gamified setting produced longer and more effective reviews. Another study by Indriasari et al. [17] introduced an energy bar mechanic to encourage earlier review submissions. The energy bar started at the maximum points value and gradually decreased each day, rewarding earlier submissions with higher points.

While these works by Indriasari demonstrate the effectiveness of gamification in enhancing reviewer motivation and the quality of peer feedback, their designs focus exclusively on the reviewing role. This limits opportunities for students to experience engagement and recognition as authors when submitting their own code for review.

Consequently, only half of the learning experience is gamified, leaving a motivational gap for acknowledging contributions in coding. Furthermore, relying solely on extrinsic rewards such as points, leaderboards, badges, and time-based mechanics may generate short-term engagement but may not fully address the deeper motivational needs of today's Generation Z learners, who dominate higher education classrooms.

METHODOLOGY

The research methodology outlines the CODUAL framework's theoretical foundations, the design of its gamification mechanics, and alignment with the dimensions of Self-Determination Theory (SDT). It begins by establishing the theoretical principles that guide the study and justify the integration of gamification in an educational context. The framework incorporates points, leaderboards, and badges within a dual-role structure, enabling students to engage as both authors and reviewers. This design is examined for its potential to satisfy the core psychological needs of autonomy, competence, and relatedness, thereby fostering motivation, enhancing engagement, and enriching the overall peer code review experience.

Theoretical Foundations

SDT is a prominent theory of human motivation that conceptualizes individuals as inherently active and self-directed [18], [19]. The theory was developed by Edward Deci and Richard Ryan in 1971 which resulting as one of the notable theories of motivation in psychology. The theory is driven by three dimensions that includes autonomy, competence and relatedness. The interrelated of these three dimensions in SDT empirically evaluated which shows promising results in enhancing student learning goals such as such as pursuit to maximize mastery knowledge and rejecting partial understanding [20]. The autonomy in SDT can be defined as the obligation of allowing to experience sense of options, inclination and desire as one behaves [21]. In other words, a person is motivated in doing something based on their freedom in making choices and taking actions. As for the competence, it can refer as an individual feeling capable in one's actions that satisfies a core psychological need in increasing intrinsic motivation, engagement, and achievement across educational, occupational and health domains [22].

Many studies shows that when a person perceive themselves as competent, consistently boost their motivation and well-being while its suppression poorer outcomes [23], [24]. Last but not least, the relatedness in SDT reflects the need to form meaningful connection with others and feel sense of belonging within groups. Studies demonstrate that relatedness provide a significant predictor regards to motivation across various contexts either in education, work and physical activity. Ultimately, the power of SDT lies in its integrated component that includes autonomy, competence, and relatedness to create the psychological bedrock for self-motivated, and persistent in learning. Therefore, operating individually for each of these dimensions in SDT is not recommended. In fact, it should work interdependently in educational setting to have a successful highly engaged learning environment. Figure one demonstrates the three dimensions of SDT.

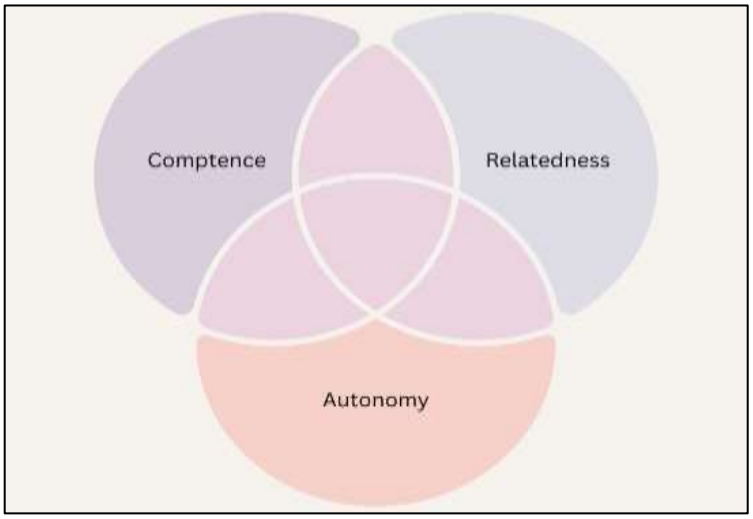

Fig 1. SDT Dimensions

Since SDT strong emphasis on fulfilling basic psychological needs which aligns closely with the Generation Z behaviour, numerous studies have successfully leveraged it to improve the engagement among this cohort. For instance, a qualitative study conducted interviews with the Generation Z employees examine the workplace leadership that satisfies all SDT dimensions does nurtures more into meaningful relationships [25]. Another study found that Generation Z employees experience greater job satisfaction in workplaces that offering flexible work practices, rewards and recognition, and competitive compensation and benefits as demonstrated through their quantitative analysis [26]. Meanwhile in education context, a study that utilizing SDT as a solution to reduce smartphone dependency among Generation Z students in onsite classroom shows viable results which is 62.1% expressed willingness to maintain the SDT [27]. As a results from these studies, it evidently confirms that SDT does increasing in motivation among the Generation Z either in a workplace or classroom. Without a doubt, the application of SDT in PCR with gamification framework such as CODUAL, allows the motivation to have a richer engagement experience that bridging the gap between industry practices and learning environment. The next section is highlighting the gamification approaches in CODUAL and how its incorporating SDT by mapping its game mechanics to autonomy, competence and relatedness.

The Proposed Framework

As aforementioned before, CODUAL is grounded with the SDT and embedded with gamification approach to enhance Generation Z learners in engagement within PCR activity. Unlike the existing gamification approaches in PCR, which predominantly focuses on the reviewer role only, this framework encompasses two roles which includes coder (code creator) and reviewer (code reviewer). This dual-role paradigm strategically stimulates autonomy, competence and relatedness among students. Prior detailing the roles and game mechanics of CODUAL, the assessment lifecycle must be established first. The following subsections are explaining on how the assessment is being initiated, the roles and workflow, the gamification mechanics and the SDT alignment justification in pertaining to CODUAL. Meanwhile, Figure one shows the overview of the framework.

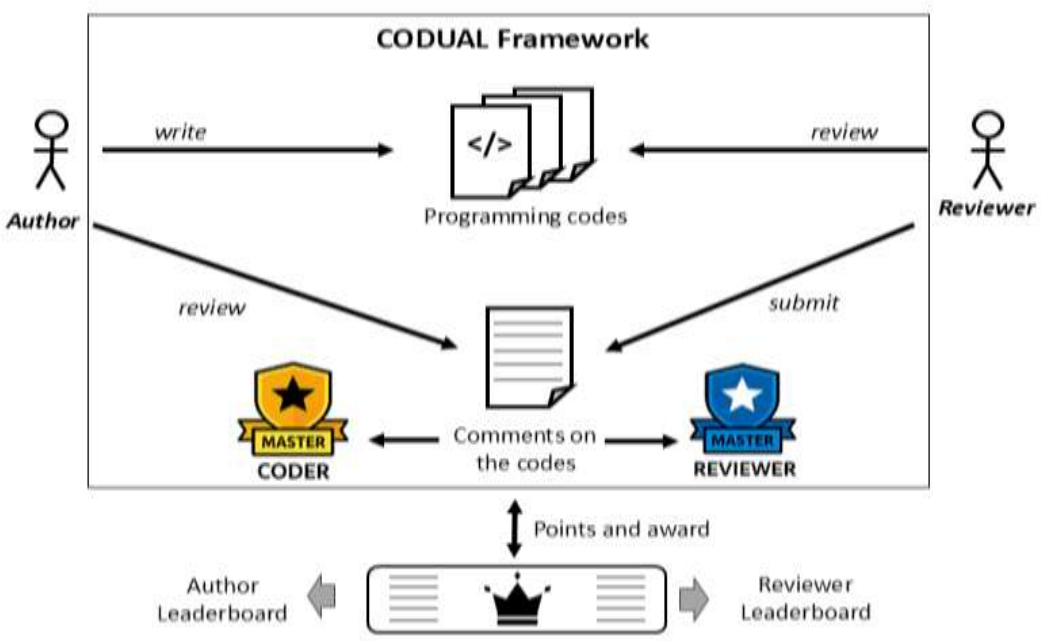

Fig 2. CODUAL Framework Overview

Assessment Initiation

The PCR in this framework begins with the instructor defining the overall schedule and evaluation structure that will guide the activity. This includes setting start and end dates for four phases: (i) the code-submission window (week one), (ii) the peer-review window (week two), (iii) the feedback assessment and agreement window (week three), and (iv) the finalization and publication window for ranks, scores, and badges (week four). The instructor also establishes the evaluation items for assessing code quality, with the flexibility to set an unlimited number of items. Each item is rated using a standardized Likert Scale where zero represents Strongly Disagree, one

represents Disagree, two represents Neither Agree nor Disagree, three represents Agree, and four represents Strongly Agree. The number of evaluation items directly determines the number of ratings a coder will receive from reviewers and the number of ratings a reviewer will receive from coders when their feedback is assessed.

Assessment Flow and Game Mechanics

Each student participates in three assessment weeks. In week one, the student takes the role of the coder, submitting their work before the deadline. In week two, the student switch role to reviewer, assigned by the system to evaluate one peer's code submission. The reviews are made randomly and anonymously to ensure fairness and avoid bias. When in the coder role, the student's score is determined entirely by reviewer ratings. The number of ratings a coder receives directly matches the number of evaluation items set by the instructor. For example, if there are three evaluation items, the reviewer provides three Likert ratings, one for each item, and the coder's total score is the sum of these values. If the scores for each evaluation item are one (Agree), four (Strongly Agree), and three (Agree), the coder earns 10 points out of a possible 12. These scores are calculated after the code submission phase ends, typically in the second week when the review process begins. In week three, coders can view their rank and the scores provided by reviewers in week two. They then evaluate the comments they received, assigning a Likert-scale score for each comment corresponding to the evaluation items. This evaluation reflects the coder's level of agreement with the feedback provided and determines the reviewer's score. For example, if three comments correspond to three evaluation items, the coder might rate them as three (Agree), two (Disagree), and two (Disagree), giving the reviewer a total score of seven out of 12. By week four, students can view their updated ranks and scores for both roles.

To further enhance engagement and reward performance in both roles, this framework includes awards such as badges to coders and reviewers based on their total percentage scores. For coders, the percentage is calculated from reviewer ratings on their submitted code. Achieving between 80% and 100% earns the Master Coder badge, reflecting top-tier coding performance. Scoring between 60% and 79% earns the Elite Coder badge, representing consistent, high-quality work. A score between 50% and 59% awards the Apprentice Coder badge, indicating developing skills. Scores below 50% result in the Inactive Coder badge, signalling minimal engagement or poor performance. Table one summarizing the badges earn by the coders based on the score percentages.

TABLE I. Badges earn by the coders

Score in percentage (%)	**Badges**
≥ 80%	Master Coder
60% to 79%	Elite Coder
50% to 59%	Apprentice Coder
< 50%	Inactive Coder

For reviewers, the percentage is derived from coder agreement ratings on the feedback comments. Achieving between 80% and 100% earns the Master Reviewer badge, demonstrating exceptional ability to provide valuable and well-received feedback. Scoring between 60% and 79% earns the Elite Reviewer badge, representing consistently useful contributions. A score between 50% and 59% results in the Apprentice Reviewer badge, indicating developing reviewing skills. Scores below 50% receive the Inactive Reviewer badge, signalling minimal or ineffective engagement in the feedback process. Table one depicting the badges earn by the reviewers based on the score percentages.

TABLE II. Badges earn by the reviewers

Score in percentage (%)	**Badges**
≥ 80%	Master Reviewer
60% to 79%	Elite Reviewer

50% to 59%	Apprentice Reviewer
< 50%	Inactive Reviewer

All scores from both roles are displayed on a dynamic leaderboard, updated at the end of each review cycle. The leaderboard serves two functions: it allows students to see how their performance compares to peers, fostering a sense of healthy competition, and it provides a public recognition platform for top performers. Players can track their rise through the ranks over time, aiming not only for higher badges but also for improved leaderboard positions. Figure two depicts the flow of the assessment, detailing the mechanics, assigned roles, and scoring system.

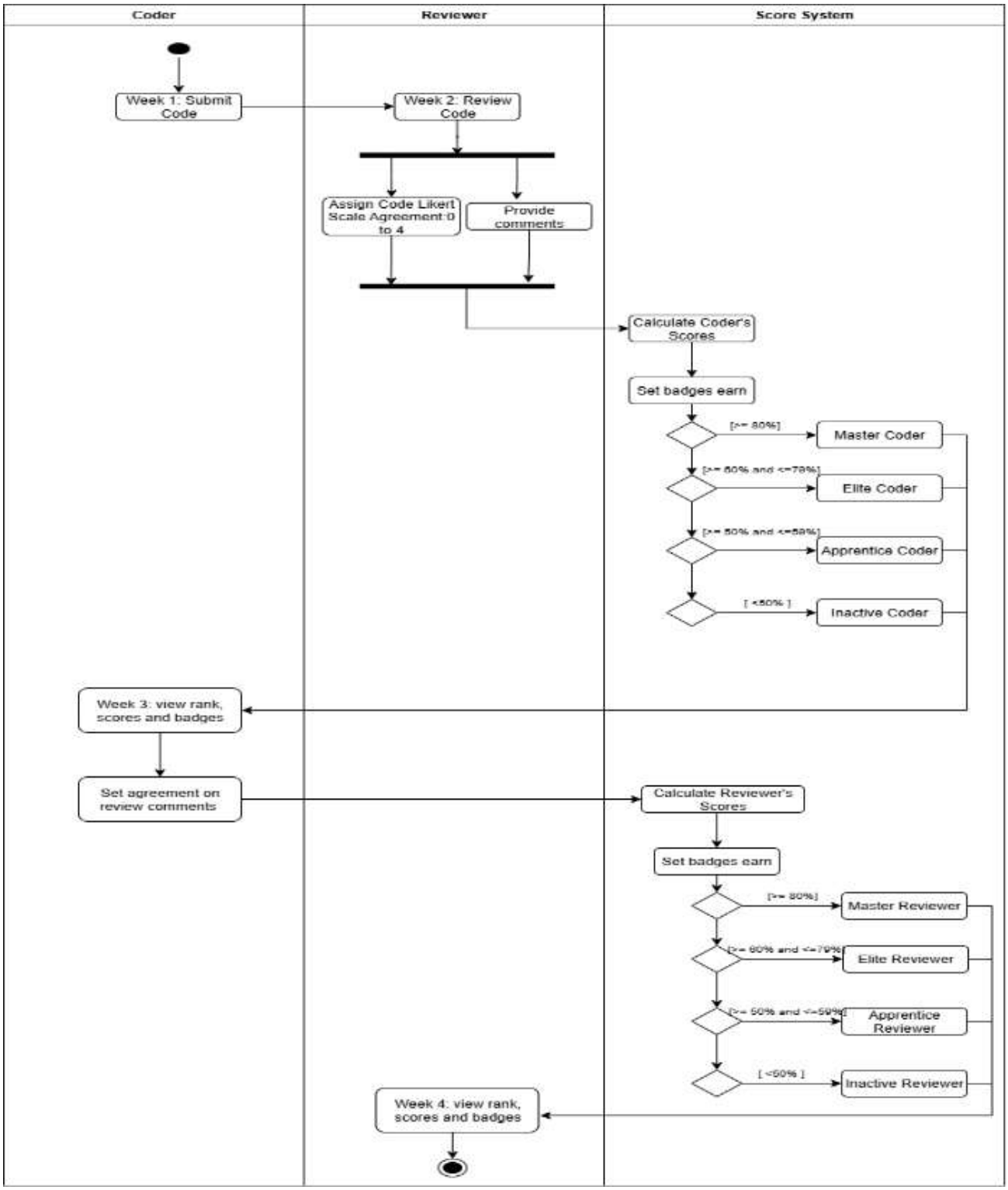

Fig 3. CODUAL Flow and Game Mechanics

1) SDT Mapping Justification

An effective way to understand the motivational potential of the CODUAL framework is to examine it through the lens of SDT, which highlights autonomy, relatedness, and competence as core psychological needs that drive intrinsic motivation. By integrating a dual-role system with separate leaderboards for authors and reviewers, the framework ensures that each role addresses these needs in a balanced and meaningful way. Table three shows the mapping outlines how each dimension of SDT is supported within the CODUAL framework.

TABLE III. SDT Mapping Justification

SDT Dimension	Justification
Autonomy	The dual-role framework allows students to act independently as both coders and reviewers, with the freedom to evaluate work, provide feedback, and influence their standing on two separate leaderboards. This gives them control over their performance in each role and ownership of their contributions.
Relatedness	Although some interactions are more specific to the coder's role and others to the reviewer role, both roles involve meaningful engagement with peers. Coders build relatedness by receiving constructive feedback, while reviewers connect through the process of giving evaluations that authors respond to. Even in anonymity, the mutual exchange fosters a sense of belonging and interpersonal relevance.
Competence	Students develop and demonstrate skills in both roles, expanding their perspective on the peer review process. As coders, they strengthen their coding abilities, and as reviewers, they refine their analytical and evaluative skills. Separate progress tracking for each role shows tangible improvement, reinforcing mastery and motivating continued development.

RESULT AND DISCUSSION

The CODUAL framework will be adopted in a future study to evaluate its impact in an actual course setting. The planned evaluation will use a post-test only non-equivalent control group design at the Faculty of Information and Communication Technology (FTMK), University Technical Malaysia Melaka (UTeM), involving undergraduate students in the Programming Technique course. The experimental group will use the gamified CODUAL system, while the control group will use a non-gamified version of the same platform.

The results of the quasi-experimental study designed to evaluate the CODUAL framework against a non-gamified PCR approach. The evaluation follows a post-test only non-equivalent control group design and will be conducted at the Faculty of Information and Communication Technology (FTMK), University Technical Malaysia Melaka (UTeM). The target participants are undergraduate students enrolled in the Programming Technique course, a subject that introduces fundamental programming principles using the C++ programming language. The experimental group will use the CODUAL framework embedded in a web-based application with gamification mechanics, including points, leaderboards, and badges integrated into a dual-role structure. The control group will use the same web-based application but without gamification elements. Both groups will complete the PCR process following identical instructions, task requirements, and timelines to ensure consistency in learning objectives.

Data Collection

Two instruments will be used for data collection. The first is the Technology Acceptance Model (TAM) questionnaire, which measures perceived usefulness (PU) and perceived ease of use (PEOU). The TAM survey consists of 12 items, with six measuring PU and six measuring PEOU, each rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). This instrument will assess how well students accept the CODUAL framework as a technological tool compared to the non-gamified PCR system.

The second instrument is the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS), adapted to measure engagement experience within the CODUAL activity. Only the satisfaction items will be used, with three items for each SDT dimension: autonomy, competence, and relatedness. These items will be rated on a five-point Likert scale, with higher scores indicating greater satisfaction of the respective psychological need. This instrument will evaluate how effectively CODUAL supports intrinsic motivation by fulfilling the core psychological needs of students.

In addition to the self-reported measures of TAM and BPNSFS, the study will incorporate objective performance metrics to strengthen validity and reduce potential bias from self-reporting. For authors, code quality will be assessed using indicators such as cyclomatic complexity and adherence to coding standards. For reviewers, review quality will be evaluated based on the completeness, constructiveness, and alignment of feedback with instructor benchmarks. This triangulation of subjective and objective data will provide a more comprehensive understanding of CODUAL's impact on both perceived engagement and actual performance.

Descriptive Statistics

The descriptive statistics, including the mean, median, and mode, will be computed for each construct in both TAM (PU and PEOU) and BPNSFS (autonomy, competence, and relatedness) for the CODUAL and control groups. These values will provide an overview of the central tendency and distribution of responses, offering initial insights into differences between groups in both technology acceptance and engagement experience. It is anticipated that the CODUAL group will score higher across all constructs compared to the control group, reflecting stronger system acceptance and greater psychological need satisfaction.

Inferential Analysis

Following the descriptive analysis, independent samples t-tests will be conducted to determine whether there are statistically significant differences between the CODUAL and control groups for each TAM construct (PU and PEOU) and each BPNSFS dimension (autonomy, competence, and relatedness). It is hypothesised that the CODUAL group will score significantly higher across all dimensions, indicating that the gamification elements embedded in the dual-role structure positively influence both acceptance of the system and engagement experience during the PCR activity.

Interpretation of Findings

The expected findings would suggest that the CODUAL framework not only improves technology acceptance but also enhances engagement by fulfilling the core psychological needs of autonomy, competence, and relatedness. Higher PU and PEOU scores would demonstrate that the system is perceived as useful and easy to use, while higher BPNSFS scores would indicate that the gamified dual-role design supports sustained motivation and meaningful participation. These results would align with prior research showing that gamification can positively affect both user acceptance and intrinsic motivation in educational contexts. Furthermore, the combination of TAM and BPNSFS outcomes would provide comprehensive evidence of CODUAL's effectiveness in bridging the gap between technological usability and motivational design.

CONCLUSION

This paper has presented CODUAL, a novel dual-role gamified framework for peer code review that integrates points, leaderboards, and badges across both the author and reviewer roles, addressing limitations in existing approaches that focus solely on reviewing. Grounded in SDT, CODUAL is designed to fulfil autonomy, competence, and relatedness while enhancing the quality of both code submissions and peer feedback. A quasi-experimental study is planned at the FTMK, UTeM with Programming Technique students, comparing CODUAL with a non-gamified PCR platform using the TAM for system acceptance and the BPNSFS for engagement experience. The anticipated results are that the CODUAL group will demonstrate higher acceptance and motivation, with future work focusing on implementing the prototype in a live course setting, comparing the outcomes with the non-gamified approach, and using the findings to refine the framework for broader application and long-term impact on collaborative skills, code quality, and sustained learner engagement.

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