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ENHANCING STUDENT MOTIVATION IN PROGRAMMING EDUCATION THROUGH N-EGM-BASED GAMIFICATION: A MOBILE APPLICATION APPROACH

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ABSTRACT
Programming education continues to face persistent challenges, including high cognitive load, abstract syntax complexity, and declining intrinsic motivation among students. Although gamification has been widely adopted to address these issues, existing frameworks such as MDA and Octalysis lack structured personalization and socialization mechanisms tailored specifically for programming learning contexts. This study proposes a mobile-based programming learning application designed using the Newton Enhanced Gamification Model (N-EGM) and empirically evaluates its effectiveness through the Hedonic Motivation System Adoption Model (HMSAM). The study involved 116 undergraduate Informatics students selected using purposive sampling. Data were collected using validated questionnaire instruments and analyzed through descriptive statistics, reliability testing, multiple regression analysis, multicollinearity diagnostics, and common method bias detection using SPSS. The findings indicate that gamification elements mapped through the N-EGM framework explain 99.1% of the variance in student motivation and 98.9% of the variance in engagement ($p < 0.001$). Leaderboard and Objective elements were the strongest predictors of motivation, while Economy and Quest significantly influenced immersion. Multicollinearity diagnostics confirmed acceptable VIF values (< 5), and Harman's single-factor test indicated no critical common method bias. Theoretically, this study contributes by integrating a structured multi-layer gamification framework with a hedonic adoption model in a programming education context. Practically, it provides a systematic design blueprint for implementing adaptive and socially integrated gamification strategies in mobile STEM learning environments.
Keywords: *Gamification, HMSAM, N-EGM, Programming, Motivation, Engagement*

1. Introduction

In recent years, the popularity of gamification has significantly increased, as evidenced by the growing number of studies and publications in this area (Bitrian et al., 2021). Gamification refers to the method of incorporating game design elements, such as challenges, points, and rewards into non-game systems (Zakaria et al., 2020). These elements leverage innate human drives for competition, achievement, and progress, aiming to enhance interactivity, improve learning processes, encourage behavioral change, and promote user engagement (Ulmer et al., 2020). Gamification has been applied across a variety of domains, including health, business, and education (de Armas et al., 2019).

Programming education is widely recognized as cognitively demanding due to the need for abstract reasoning, algorithmic thinking, and precise syntax usage. Empirical studies report high dropout rates and significant levels of programming anxiety in introductory computer science courses (Becker & Quille, 2021; Fagerlund et al., 2022). Recent studies further indicate that programming anxiety, low self-efficacy, and lack of sustained motivation significantly contribute to student attrition in computing courses (Dirzyte et al., 2023; Wolz et al., 2022; Pan & Harun, 2025). These findings highlight the necessity of instructional interventions that not only address cognitive complexity but also mitigate emotional barriers and persistence challenges in programming education.

Cognitive load theory suggests that programming tasks frequently exceed learners' working memory capacity, leading to frustration and reduced intrinsic motivation (Ihantola et al., 2020). These persistent challenges indicate that instructional approaches must address not only conceptual complexity but also motivational sustainability. Although gamification has been widely implemented in education, existing frameworks such as MDA and Octalysis primarily emphasize structural mechanics or psychological motivation drivers without integrating adaptive learner profiling and structured socialization mechanisms specific to programming education (Sailer & Homner, 2020; Dichev & Dicheva, 2017). Furthermore, while the Newton Enhanced Gamification Model (N-EGM) proposes a multi-layer framework for STEM learning (Zhao et al., 2021), empirical validation of its motivational mechanisms through hedonic adoption models remains limited, particularly in mobile programming environments.

In the context of education, gamified learning applications have shown effectiveness in boosting students' motivation and engagement (Major & Silva, 2023; Toda et al., 2019; Zhao et al., 2021; Wang et al., 2022). Such applications are considered gamified if users experience gameplay-like interactions while using them. Educators utilize this approach to create more interactive and enjoyable learning environments. The integration of gamification in mobile systems also adds the benefit of flexibility and accessibility, supported by real-time updates and widespread mobile device usage (Hidayat et al., 2020; Bitrian et al., 2021).

Programming is a field that requires consistent effort and a specific approach to learning (Cheah, 2020). Many students, including those majoring in computer science, often struggle with understanding fundamental programming concepts, which can lead to frustration and decreased motivation (Major & Silva, 2023; Polito & Temperini, 2021). A quantitative survey conducted among undergraduate Informatics students at Institut Teknologi Del, involving 116 samples selected from 163 respondents using the Slovin formula, revealed that a majority of them face difficulties in learning basic programming.

Although gamification has been shown to improve motivation and engagement in learning contexts, the inappropriate selection or implementation of gamification elements may have adverse effects on the learning process (Cuervo-Cely et al., 2022). Moreover, commonly used gamification frameworks such as MDA, Octalysis, and D6 are often criticized for lacking emphasis on personalization and socialization, critical components in the context of programming education, which demands active participation and sustained interest. To address this limitation, Zhao et al. (2021) introduced the Newton Enhanced Gamification Model (N-EGM), a multi-layered framework tailored for STEM education. The model offers a more structured and holistic approach by integrating emotional, cognitive, social, and motivational aspects. To our knowledge, N-EGM has only been evaluated once in prior studies, with only a single prior study reporting its effectiveness in enhancing student comprehension and engagement with a 95% confidence level.

Despite the growing adoption of gamification in programming education, existing implementations often lack a theoretically grounded integration between gamification mechanics and validated motivational models. Prior evaluations of the N-EGM framework have primarily been conducted in controlled experimental settings (Zhao et al., 2021), limiting the ecological validity and real-world applicability of the findings.

Addressing this gap, this study develops a mobile-based gamified programming application grounded in the N-EGM framework and empirically validates its effectiveness in an authentic learning environment. Beyond implementation, this research integrates the Hedonic-Motivation System Adoption Model (HMSAM) to systematically examine the relationships between user interaction, intrinsic motivation, perceived usefulness, and behavioral intention (Oluwajana et al., 2019). By combining N-EGM with hedonic motivational modeling in a real-world mobile programming context, this study contributes both practically through the development of a validated educational prototype and theoretically by extending the empirical validation of N-EGM beyond controlled laboratory conditions.

This study addresses the following research questions:

RQ1: How do gamification elements mapped through the N-EGM framework influence student motivation and engagement in programming education?

RQ2: How does HMSAM validate the motivational pathways of N-EGM in a mobile-based programming learning context?

2. Literature Review

Gamification Elements in Education

Gamification is the use of game elements in non-game contexts to enhance user motivation, engagement, and behavior (Zakaria et al., 2020). It is not merely about creating games, but about applying game-thinking, design strategies, and feedback systems to solve real-world problems (Marisa et al., 2020; Siahaan et al., 2025). When applied effectively, gamification transforms routine or instructional tasks into interactive experiences that resemble gameplay, making them more appealing and enjoyable for users.

In educational contexts, a number of educational applications have successfully implemented gamification to enhance learner engagement and motivation. Applications such as Duolingo, Quizizz, Kahoot, Pahamify, Programming Hero, Sololearn, Mimo, CodingX, and Enki have shown how integrating game-like features can make learning more interactive and enjoyable.

Beyond individual case studies, several meta-analyses have confirmed the overall effectiveness of gamification in improving learning outcomes and student engagement. Bai et al. (2020) reported that gamification has a statistically significant positive effect on academic performance across various educational levels. Similarly, Li et al. (2023) found moderate to strong effect sizes in motivation and engagement through meta-analytic synthesis. Specifically in programming education, Zhan et al. (2022) demonstrated that gamification significantly enhances students' learning outcomes and persistence in coding-related courses. These findings provide strong empirical justification for the structured implementation of gamification elements in educational systems.

One of the most widely adopted gamification elements is acknowledgement, often represented in the form of badges, medals, or trophies. These serve as positive feedback for users who accomplish specific tasks or exhibit desired behaviors, such as completing challenges or collaborating with peers (Toda et al., 2019; Hamari et al., 2016; Groening & Binnewies, 2019). However, excessive or meaningless acknowledgements may lead to reduced motivation, as users might perceive them as lacking value. Similarly, the overuse of competitive or assessment-based gamification may produce unintended negative effects, such as increased performance pressure, reduced intrinsic motivation, or superficial engagement, particularly when competition overshadows learning objectives (Kwon & Özpolat, 2021).

Progression is another core element, commonly visualized through a progress bar, which allows users to track how far they have advanced in their learning journey. This visual feedback has been shown to boost learner motivation by providing a clear sense of achievement and direction (de Armas et al., 2019; Toda et al., 2019; Hamari et al., 2016; Aditya et al., 2024). Nonetheless, slow visible progress may lead to frustration, especially if users feel their efforts are not rewarded adequately.

The use of points as feedback for task completion, such as quizzes, assignments, or even attendance aligns with operant conditioning theory, reinforcing desired behaviors through consistent reward mechanisms (Wang et al., 2022). Closely related are stats, which present detailed user performance data like task completion counts or highest scores. These statistical representations help learners reflect on their progress and increase self-awareness (Toda et al., 2019; Deterding et al., 2011).

Another important aspect is rewards, including virtual goods, feature access, or symbolic recognition. These serve as positive reinforcement for user actions and can significantly enhance engagement when designed meaningfully (de Armas et al., 2019). Some applications also include a degree of chance through random rewards or outcome variations based on timing or accuracy, adding surprise and excitement (Anderson & Rainie, 2012). However, when randomness feels unfair, it may undermine the user's motivation.

Gamified systems also implement economy elements, where users can exchange collected points for items or privileges within a virtual marketplace. This transactional aspect supports goal-setting behaviors and enhances user retention (Hamari et al., 2016). Similarly, time pressure is often used to add urgency where completing tasks within time limits can yield greater points or rewards thus simulating real-time challenges (Wang et al., 2022; Plass et al., 2015). Still, excessive time constraints may lead to anxiety and reduce engagement.

To structure the learning experience, block activities are often applied, requiring users to complete certain prerequisites before unlocking new content. This approach builds curiosity and encourages a step-by-step mastery of content (de Armas et al., 2019). In line with that, clearly defined objectives in each learning task are essential to ensure users stay motivated and focused, although overly difficult goals may backfire (Toda et al., 2019; Locke & Latham, 2002).

Social elements also play a vital role. Through social interaction areas such as discussion forums and collaborative features, learners can connect, clarify doubts, and enhance understanding (Cuervo-Cely et al., 2022). In competitive environments, leaderboards are commonly used to display user rankings, which can motivate learners through healthy competition. Nevertheless, overly intense competition may result in discomfort or demotivation (Wang et al., 2022; Hamari et al., 2016; Aditya et al., 2024).

Additional game-like features include quests, which function as learning challenges (e.g., quizzes or puzzles) that reinforce comprehension and often scale in difficulty based on the learner's progress (Aditya et al., 2024). In digital learning environments, gamified quizzes have been shown to significantly improve engagement, immediate feedback responsiveness, and knowledge retention (Zainuddin et al., 2020). These tie directly into the leveling system, where users unlock higher-level tasks as they accumulate experience, thus reflecting the growth of their abilities (Toda et al., 2019; Wang et al., 2022).

Lastly, avatars serve as personal visual representations of users in the system. These customizable characters not only promote user identity and emotional attachment to the learning platform but also enhance motivation through personalization and a sense of ownership (Toda et al., 2019).

Altogether, these elements work synergistically to foster engagement, support learner autonomy, and sustain motivation in educational settings. However, their effectiveness depends heavily on thoughtful and balanced implementation, aligned with learning objectives and user preferences.

Gamification Frameworks

While individual gamification elements provide foundational motivation, a structured gamification framework is crucial for designing a comprehensive and coherent learning experience. Frameworks help developers and educators align game mechanics with educational goals and learner needs.

Two of the most well-known frameworks are MDA (Mechanics-Dynamics-Aesthetics) and Octalysis. The MDA framework focuses on the relationship between the components of game design: mechanics (rules and features), dynamics (player interactions), and aesthetics (emotional responses) (Putra & Yasin, 2021). Although MDA offers a systematic way to understand game design, it has been criticized in educational contexts for emphasizing game-like experiences rather than pedagogical effectiveness and lacking structured personalization mechanisms tailored to diverse learner profiles (Klock et al., 2020; Oliveira et al., 2023).

Meanwhile, the Octalysis Framework, developed by Yu-kai Chou, identifies eight core drives that influence user motivation, including achievement, ownership, scarcity, and social influence (Fathian et al., 2021; Bernik, 2021; Christopher & Waworuntu, 2021). Octalysis offers valuable psychological insights, but its abstract nature and complexity may pose challenges for educators without game design backgrounds. Furthermore, similar to other generalized gamification frameworks, it does not explicitly incorporate adaptive personalization or learner modeling mechanisms required in formal educational settings (Hong et al., 2024; Oliveira et al., 2023).

To address these limitations, Newton Enhanced Gamification Model (N-EGM) was introduced. This model offers a layered and integrated structure, designed specifically for STEM education environments. Unlike MDA and Octalysis, N-EGM incorporates socialization layers, encouraging collaboration and peer interaction key components often underemphasized in other models (Zhao et al., 2021). Furthermore, N-EGM emphasizes the role of technology integration, including personalized recommendations and learning analytics, to support adaptive learning paths. It simplifies the gamification process while maintaining flexibility, making it accessible for educators and effective for learners. By providing clear mapping between game elements and educational outcomes, N-EGM supports deeper engagement and skill development. While MDA and Octalysis remain useful for general gamification design, N-EGM's targeted approach better aligns with the specific learning objectives and challenges in introductory programming courses. A comparison of the three frameworks is presented in Table 1.

Table 1 - Comparison of Gamification Framework

Framework	Focus	Strengths	Limitations	Relevance to Study
MDA	Game mechanics, player interaction, aesthetics	Provides systematic structure for analyzing game experiences	Lacks focus on education and personalization	Low
Octalysis	Psychological motivation (8 core drives)	Offers deep insight into intrinsic/extrinsic motivation	Too abstract and complex for non-experts	Medium
N-EGM	Education-focused gamification for STEM	Supports personalization, collaboration, and adaptive learning paths	Limited empirical validation so far; relatively new framework	High

System Evaluation Model

In evaluating user acceptance and engagement with technology-based systems, several models have been developed. One of the most widely used is the Technology Acceptance Model (TAM), introduced by Davis (Yan et al., 2022). TAM posits that technology acceptance is influenced by two primary factors: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). This model emphasizes users' cognitive assessments regarding how useful and easy a system is to use, which in turn affect their behavioral intention to adopt the technology(Fitria et al., 2024). TAM is considered a generic model and has been extensively applied across various information system contexts, particularly those that are utilitarian in nature(Wijaya et al., 2026).

However, TAM has notable limitations, especially in contexts where the system aims not only to accomplish tasks but also to provide pleasurable or hedonic experiences, such as in games or gamified applications. In such contexts, emotional and intrinsic motivations often play a more significant role than utilitarian motivations. As a result, TAM may fall short in capturing these experiential aspects, making it less suitable for evaluating systems with strong hedonic components.

Another model, the Expectation-Confirmation Model (ECM), has been employed as an alternative, particularly for evaluating user satisfaction and continued system use. ECM is based on the comparison between users' initial expectations and their post-usage experiences. While ECM provides valuable insights into post-adoption behaviors, it remains centered on satisfaction-related constructs and does not explicitly account for hedonic or affective factors that may arise in user interactions with gamified systems.

Given these limitations, this study adopts the Hedonic-Motivation System Adoption Model (HMSAM), which builds upon TAM and ECM by integrating constructs specifically designed to evaluate systems with hedonic characteristics, such as those involving gamification (Oluwajana et al., 2019). Unlike TAM and ECM, which emphasize cognitive and utilitarian aspects, HMSAM expands the evaluation framework by incorporating variables such as Perceived Enjoyment, Curiosity, Control, and Focused Immersion. These constructs had better reflect users' intrinsic motivation and emotional engagement when interacting with a system.

The adoption of HMSAM is particularly relevant in this study, as the application under evaluation integrates various gamification features aimed at enhancing user motivation and engagement. The implementation of HMSAM involves several stages, including the identification of evaluation objectives, the design of survey instruments based on HMSAM indicators, the collection of user data, and data analysis.

By applying the HMSAM framework, this study offers a more comprehensive understanding of how gamification elements influence user behavior both individually and collectively. The interpretation of results derived from this analysis serves as a foundation for formulating design recommendations and future system enhancements. Consequently, decision-making is grounded in empirical data and supports the continuous improvement of application quality.

Theoretical Framework Synthesis

Previous studies have demonstrated that gamification can effectively enhance learning motivation and engagement. However, the inappropriate selection of gamification elements may lead to decreased motivation. Therefore, this study adopts the Newton Enhanced Gamification Model (N-EGM) as it addresses the limitations of frameworks such as MDA and Octalysis by incorporating personalization and socialization aspects that are highly relevant in educational contexts. Furthermore, to evaluate the effectiveness of the developed system, the Hedonic-Motivation System Adoption Model (HMSAM) is utilized, as it specifically measures user interaction from the perspectives of motivation and engagement, which are the central focus of this study.

Conceptual Framework

Based on the synthesis of the Newton Enhanced Gamification Model (N-EGM) and the Hedonic-Motivation System Adoption Model (HMSAM), this study proposes a conceptual framework integrating gamification elements, motivational constructs, and learning outcomes. The selected 14-gamification elements structured within the N-EGM layers are hypothesized to influence users’ perceived ease of use, usefulness, curiosity, joy, and control. These constructs subsequently affect behavioral intention and flow/immersion, ultimately contributing to student motivation and engagement in programming education. The proposed conceptual framework is illustrated in Fig. 1.

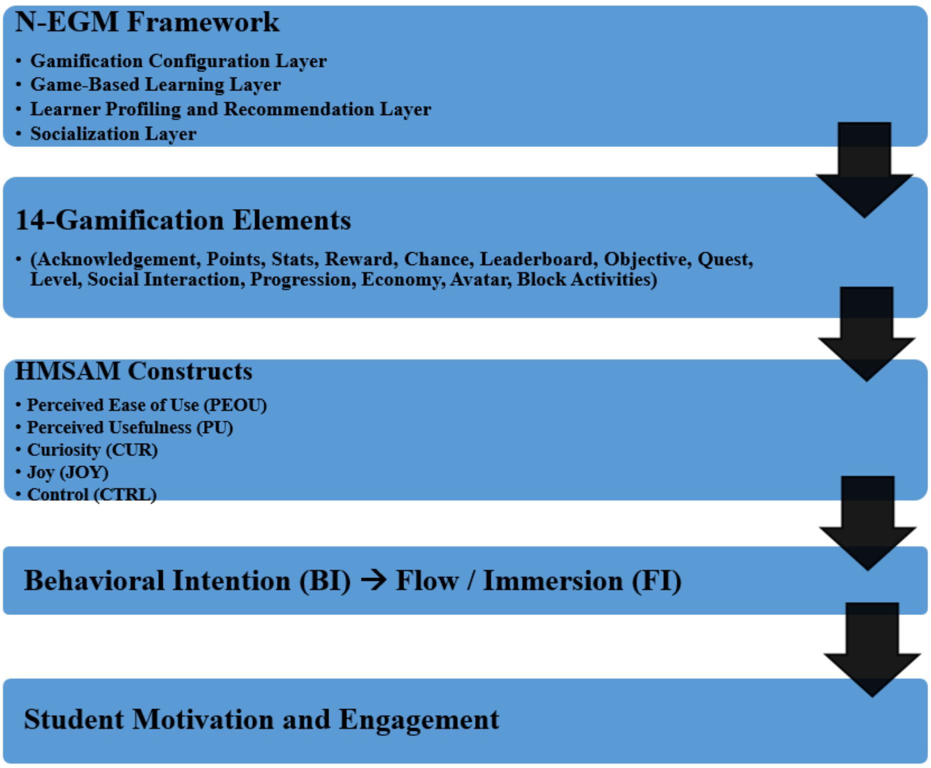

Fig. 1. The Proposed Conceptual Framework

Comparative Analysis of Gamification Approaches

Digital Game-Based Learning (DGBL) emphasizes immersive game experiences but often requires full-scale game development, limiting scalability in structured academic contexts. Problem-Based Learning (PBL), although effective for fostering conceptual understanding, does not inherently integrate systematic motivational reinforcement (Major & Silva, 2023). The GameFlow model focuses on flow conditions and player enjoyment but lacks explicit adaptive personalization mechanisms. In contrast, the Newton Enhanced Gamification Model (N-EGM) integrates four layers gamification configuration, game-based learning, learner profiling, and socialization, allowing alignment between pedagogical objectives, adaptive personalization, and social engagement (Zhao et al., 2021). However, empirical validation of N-EGM within programming-specific motivational contexts remains underexplored.

3. Research Methods

This research followed a series of stages starting from a literature review and problem identification, followed by data collection and analysis, system design, implementation, and final evaluation. These stages are illustrated in Fig. 2, representing the linear and structured workflow undertaken throughout the project.

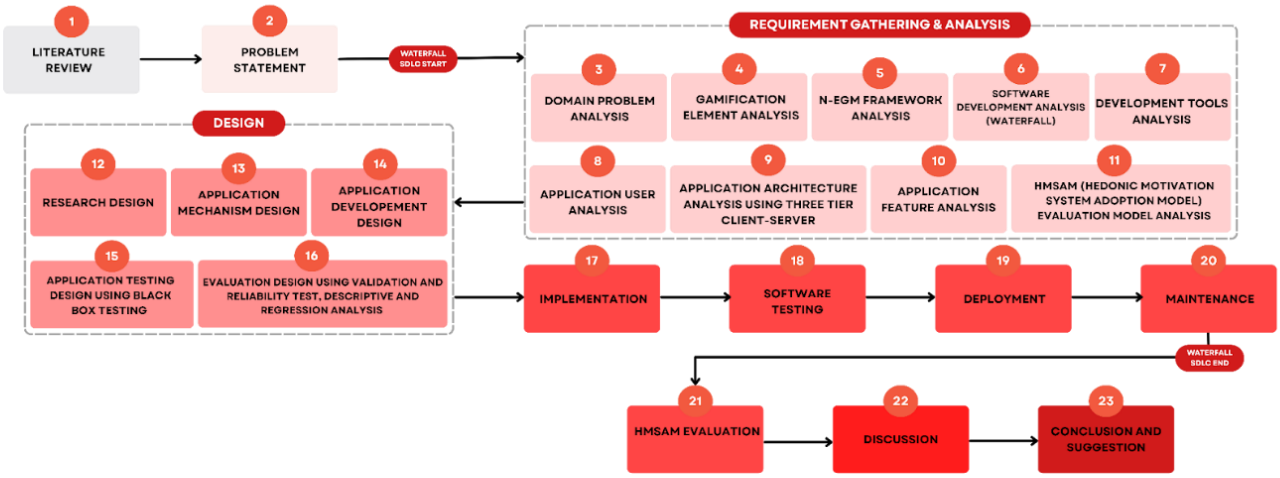

Fig. 2. Research Stages

To ensure a systematic and structured development process, the Waterfall model was used as the system development methodology. This sequential model includes stages such as requirements analysis, system design, implementation, testing and evaluation, and deployment. Each phase was carefully executed to maintain consistency and clarity in the development process. The Waterfall model was considered appropriate for this research due to the well-defined scope and stable requirements of the system being developed. Since the application aimed to integrate specific gamification elements derived from literature studies and user analysis, the system functionalities and objectives were clearly established at the beginning of the project.

The study involved 116 undergraduate Informatics students aged 18–22 years who had completed or were enrolled in programming courses. Purposive sampling was applied to ensure participants had relevant programming experience. Data were analyzed using SPSS. Reliability was assessed using Cronbach's Alpha (>0.70), validity using corrected item-total correlation (>0.30), and regression analysis was conducted to evaluate predictor relationships. Variance Inflation Factor (VIF) values ranged from 1.82 to 3.94, indicating no significant multicollinearity. Harman's single-factor test showed the first factor accounted for 32.4% of total variance (<50%), suggesting minimal common method bias.

Gamification Element Selection

The gamification elements are components that define the characteristics of a game. Based on exploratory studies from various previous research, approximately 36 unique gamification elements were identified across different domains, including educational, workplace, and health applications. Each application implemented a different combination of these elements. During the review, it was observed that several studies used similar elements with different names or terminologies. To ensure consistency, the element selection process focused on identifying uniquely named elements, where items with similar meanings but different linguistic representations were counted only once. As a result, a refined list of 36 distinct gamification elements was established, as presented in Table 2.

Table 2 - Gamification Elements Found in Literature

No	Gamification Element	[4]	[5]	[6]	[8]	[24]	[25]	[26]	Number of Occurrences
1	Leaderboard	☑	☑	☑	☑	☑		☑	6
2	Completion Progression	☑							1
3	Badge	☑			☑		☑		3
4	Quest	☑	☑						2
5	Block activities	☑							1
6	Forum	☑	☑						2
7	Surprise Element	☑							1
8	Feedback	☑	☑						2
9	Reward	☑	☑						2
10	Timer	☑							1
11	Acknowledgement			☑					1
12	Level		☑	☑			☑	☑	4
13	Progression		☑	☑			☑		3
14	Point		☑	☑	☑		☑	☑	5
15	Stats			☑					1
16	Chance			☑					1
17	Imposed choice			☑					1
18	Economy			☑					1
19	Rarity			☑					1
20	Time pressure			☑					1
21	Competition			☑					1
22	Cooperation			☑					1
23	Reputation			☑					1
24	Social pressure			☑					1
25	Novelty			☑					1
26	Objective			☑					1
27	Puzzle			☑					1
28	Renovation			☑					1
29	Sensations			☑					1
30	Narrative			☑					1
31	Storytelling		☑	☑					2
32	Achievement					☑	☑		2
33	Lives		☑						1
34	Challenge						☑		1
35	Avatar		☑				☑		2
36	Virtual Currency						☑		1

Among the 36-gamification elements identified across various sources, the elements leaderboard, points, and level were found most frequently, with occurrences exceeding three instances. These elements are considered to have strong potential as core components that should be prioritized in the implementation of gamification.

Following the identification of 36 gamification elements, a deeper analysis was conducted to determine the most relevant elements for implementation. This process involved two key stages: simplification through functional grouping and benchmarking analysis. In the simplification phase, elements with overlapping functions or similar motivational purposes were merged, resulting in a refined list of 22 representative elements, as presented in Table 3.

Two reviewers with expertise in gamification research conducted the simplification and grouping process independently. To ensure methodological rigor and reduce subjectivity, inter-rater reliability was assessed using Cohen's Kappa coefficient. The analysis yielded a Kappa value of 0.87, indicating strong agreement and consistency in element grouping decisions.

Table 3 - Simplification of Gamification Elements

No.	Initial Element	Simplified Element	Reason of Simplification
1	Acknowledgement	Acknowledgement	-
2	Badge	Acknowledgement	A badge represents a symbolic recognition of a user's accomplishment.
3	Achievement	Acknowledgment	Conceptually, achievement-based rewards serve as a form of recognition.
4	Progression	Progression	-
5	Completion progression	Progression	The completion of progress is inherently contained within the progress element itself.
6	Point	Point	-
7	Stats	Stats	-
8	Reward	Reward	-
9	Rarity	Rarity	-
10	Feedback	Social Interaction, Reward	Feedback is the response given to users, which can be facilitated through gamification elements such as social interaction and reward mechanisms.
11	Chance	Chance	-
12	Economy	Economy	-
13	Timer	Time pressure	The timer element is generally associated with creating a sense of urgency for users, and therefore can be represented by the time pressure element.
14	Time pressure	Time pressure	-
15	Block activities	Block activities	-
16	Imposed choice	Imposed choice	-
17	Surprise element	Surprise element	-
18	Competition	Leaderboard	It is already represented by the leaderboard element, which facilitates user comparison.
19	Leaderboard	Leaderboard	-
20	Reputation	Stat, Leaderboard, Acknowledgement	This element is integrated into the Stat element due to its impact on how users are perceived socially.
21	Social pressure	Stat, Leaderboard, Acknowledgement	This element is integrated into the Stat element due to its impact on how users are perceived socially.

No.	Initial Element	Simplified Element	Reason of Simplification
22	Novelty	-	The element of novelty was not introduced at this stage, as its implementation is more appropriate through continuous and iterative application development
23	Cooperation	Cooperation	-
24	Objective	Objective	-
25	Renovation	Avatar	Avatar can be seen as a representation of the renovation element, since it reflects ongoing customization and renewal.
26	Quest	Quest	-
27	Tantangan	Quest	The quest element represents a more specific and structured form of challenge.
28	Puzzle	Puzzle	-
29	Level	Level	-
30	Lives	Lives	-
31	Social Interaction	Social Interaction	-
32	Sensations	Surprise element	Sensation is intended to evoke emotional responses or experiences comparable to those triggered by surprise.
33	Narrative	Storytelling	Storytelling is regarded as adequately representing the narrative element, as it delivers narratives through stylistic expression and interactive engagement.
34	Storytelling	Storytelling	-
35	Avatar	Avatar	-
36	Mata Uang Virtual	Economy	-

To further evaluate the relevance and applicability of these elements, a benchmarking analysis was conducted on a selection of gamified learning applications. The benchmarking included nine applications, consisting of five programming-focused platforms (Programming Hero, SoloLearn, Mimo, CodingX, and Enki) and four widely-used general learning applications (Duolingo, Kahoot!, Quizizz, and Pahamify). These applications were selected based on their popularity, gamification effectiveness, and relevance to the target domain. Premium access was utilized where necessary to ensure a comprehensive exploration of features and gamification elements. By prioritizing programming-focused applications while also incorporating general gamified platforms, this study aimed to identify elements that were not only effective but also adaptable to the context of programming education. This approach also allowed the discovery of underutilized elements in programming applications that have proven successful in more general contexts. The benchmarking results are shown in Table 4, and based on this analysis, a final selection of 14 gamification elements was made. These elements were selected based on their appearance in at least six out of nine benchmarked applications and their alignment with engagement goals in programming education.

The six-out-of-nine application threshold (66%) was adopted to ensure that selected gamification elements demonstrated majority prevalence across benchmarked platforms while preventing inclusion of niche or domain-specific features that may not generalize across programming learning environments. This threshold balances representativeness and practical relevance. The selected elements are listed in

Table 5.

Table 4 - Benchmarking Gamification Elements

No.	Gamification Elements	Duolingo	Kahoot	Quizziz	Pahamify	Programming Hero	Sololearn	Mimo	CodingX	Enki	Count
1	Acknowledgment	✓	✓	✓	✓		✓	✓	✓	✓	8
2	Progression	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
3	Point	✓	✓	✓	✓	✓	✓	✓	✓		8
4	Stats	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
5	Reward	✓	✓	✓	✓	✓	✓	✓	✓		8
6	Rarity	✓			✓			✓			3
7	Chance	✓	✓	✓		✓	✓			✓	6
8	Economy	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
9	Block activities	✓	✓			✓	✓	✓		✓	6
10	Imposed choice	✓				✓	✓	✓			4
11	Surprise element		✓	✓							2
12	Leaderboard	✓	✓	✓	✓	✓	✓	✓	✓		8
13	Cooperation	✓	✓								2
14	Objective	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
15	Quest	✓	✓	✓	✓		✓	✓	✓		7
16	Puzzle	✓	✓	✓							3
17	Levelling System	✓	✓		✓	✓	✓		✓		6
18	Lives	✓					✓	✓			3
19	Sosial Interaction	✓	✓		✓	✓	✓			✓	6
20	Storytelling	✓			✓						2
21	Avatar	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
22	Time pressure	✓	✓	✓	✓						4

Table 5 - The Selected Elements

No.	Element	Number of Applications Implementing
1	Acknowledgement	8
2	Progression	9
3	Point	8
4	Stat	9
5	Reward	8
6	Chance	6
7	Economy	9
8	Block activity	6
9	Leaderboard	8
10	Objective	9
11	Quest	7
12	Level	6
13	Social interaction	6
14	Avatar	9

Mapping of Gamification Elements to the N-EGM Framework

The N-EGM (NEWTON-Enhanced Gamification Model) framework consists of four interrelated layers that work together to enhance educational experiences through gamification. These layers are Gamification Configuration, Game-Based Learning, Learner Profiling and Recommendation, and Socialization.

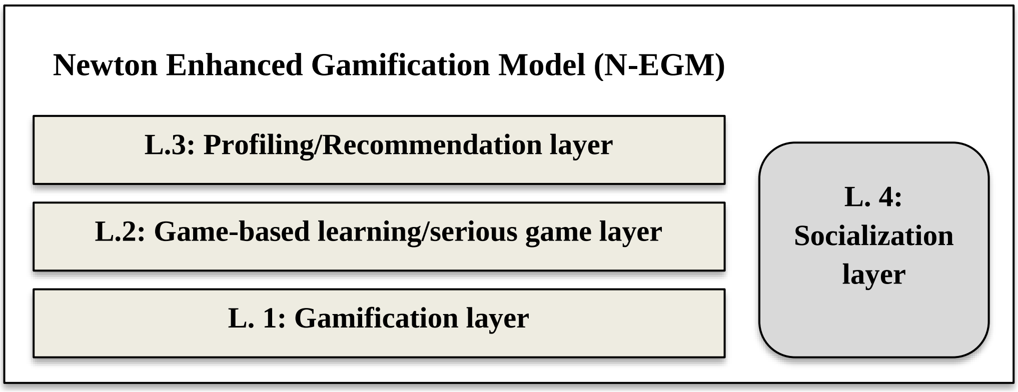

Fig. 3. N-EGM Layers

The Gamification Configuration Layer is responsible for defining the game mechanics and reward systems associated with learning content. By providing clear mechanisms, this layer establishes the foundation for a structured and engaging gamified learning experience. The Game-Based Learning Layer involves the actual use of serious games and game-based content, structured using the mechanics defined in the first layer. This layer incorporates both static interactions (e.g., quizzes) and dynamic visual elements (e.g., animations, game-like environments) to deepen user engagement through classical game dynamics and aesthetics. The Learner Profiling and Recommendation Layer aims to personalize the learning experience by tailoring content to learners' profiles. Adaptive feedback mechanisms have been shown to significantly increase engagement and sustained interaction in gamified systems, particularly when feedback is aligned with users' motivational states (Hassan et al., 2022). It collects data regarding learners' interests, preferences, progress, and behavior from the previous layers to generate intelligent recommendations and support adaptive learning paths. The Socialization Layer enhances the learning environment by introducing social features that enable peer-to-peer and student teacher interactions. This includes functions for sharing ideas, providing feedback, offering support, and engaging in collaborative activities, fostering a socially rich and supportive educational experience.

The 14-gamification elements selected in

Table *5* were mapped to the layers of the N-EGM model to support the specific objectives of each layer. This mapping process was carried out through an analytical evaluation, in which a table was constructed to determine the relevance of each element. The evaluation ensured that the selected elements were grounded in the literature and aligned with the criteria defined by the four layers of the N-EGM framework. The results of this mapping are presented in Table 6.

Table 6 - Mapping of Gamification Elements to the N-EGM Model

No.	Layer	Element	Definition	Supporting Research
1	Gamification Layer	Point	A virtual currency earned by completing tasks, which can later be exchanged for rewards.	(Oluwajana et al., 2019), (Marisa et al., 2020)
2		Acknowledgement	Visual markers awarded for reaching specific milestones or achievements.	(de Armas et al., 2019), (Oluwajana et al., 2019), (Marisa et al., 2020)

No.	Layer	Element	Definition	Supporting Research
3		Leveling system	Applied to quests to determine difficulty; higher levels correspond to more challenging tasks.	(Marisa et al., 2020)
4		Progression	A visual indicator representing the user's learning progress in percentage.	(de Armas et al., 2019)
5		Objective	Defines the main objectives users aim to achieve, providing direction and motivation.	(Toda et al., 2019), (Locke & Latham, 2002)
6		Avatar	A customizable graphical representation of the user, supporting autonomy and identity.	(Toda et al., 2019)
7		Block activities	Restricts access to certain tasks until prerequisite tasks are completed in order.	(de Armas et al., 2019)
8	Game-based Learning Layer	Quest	Daily tasks related to programming, both theoretical and practical, scaled by difficulty level.	(de Armas et al., 2019), (Oluwajana et al., 2019), (Marisa et al., 2020)
9		Chance	Allows users to earn more points when completing higher-level quests.	(Toda et al., 2019), (Anderson & Rainie, 2012)
10		Economy	A point redemption system where points can be traded for rewards in a virtual store.	(de Armas et al., 2019)
11		Reward	Recognition given for participation or achievement, often in the form of points.	(Oluwajana et al., 2019)
12	Profiling Layer	Stats	Displays user performance data such as total points, scores, and learning progress.	(Anderson & Rainie, 2012)
13		Leaderboard	Ranks users based on performance metrics like task completion and scores.	(Marisa et al., 2020)
14	Socialization Layer	Social Interaction	Facilitates user interaction through Q&A or peer discussion features.	(Pargaonkar, 2023)

System Flow Design

This gamified programming learning application involves three main roles: user (student), admin, and superadmin. Students access the application via mobile to study learning modules (topics), complete challenges (quests), and earn points that can be exchanged in the market. These points also contribute to their rank in the leaderboard, which fosters motivation and engagement through gamification elements. Admins, who access the system through the web, are responsible for managing learning content such as questions and modules. Meanwhile, the superadmin has full control over the system, including managing admin accounts, accessing user data, overseeing learning progress, and configuring the market feature. User accounts are created via a registration feature on the mobile app, while admin and superadmin accounts can only be created and managed by the superadmin to ensure system stability and maintain authority. With this role structure and feature set, the system is designed to provide an engaging, competitive, and adaptive programming learning experience for students. The complete flow of user interactions and role-based processes within the system is illustrated in Fig. .

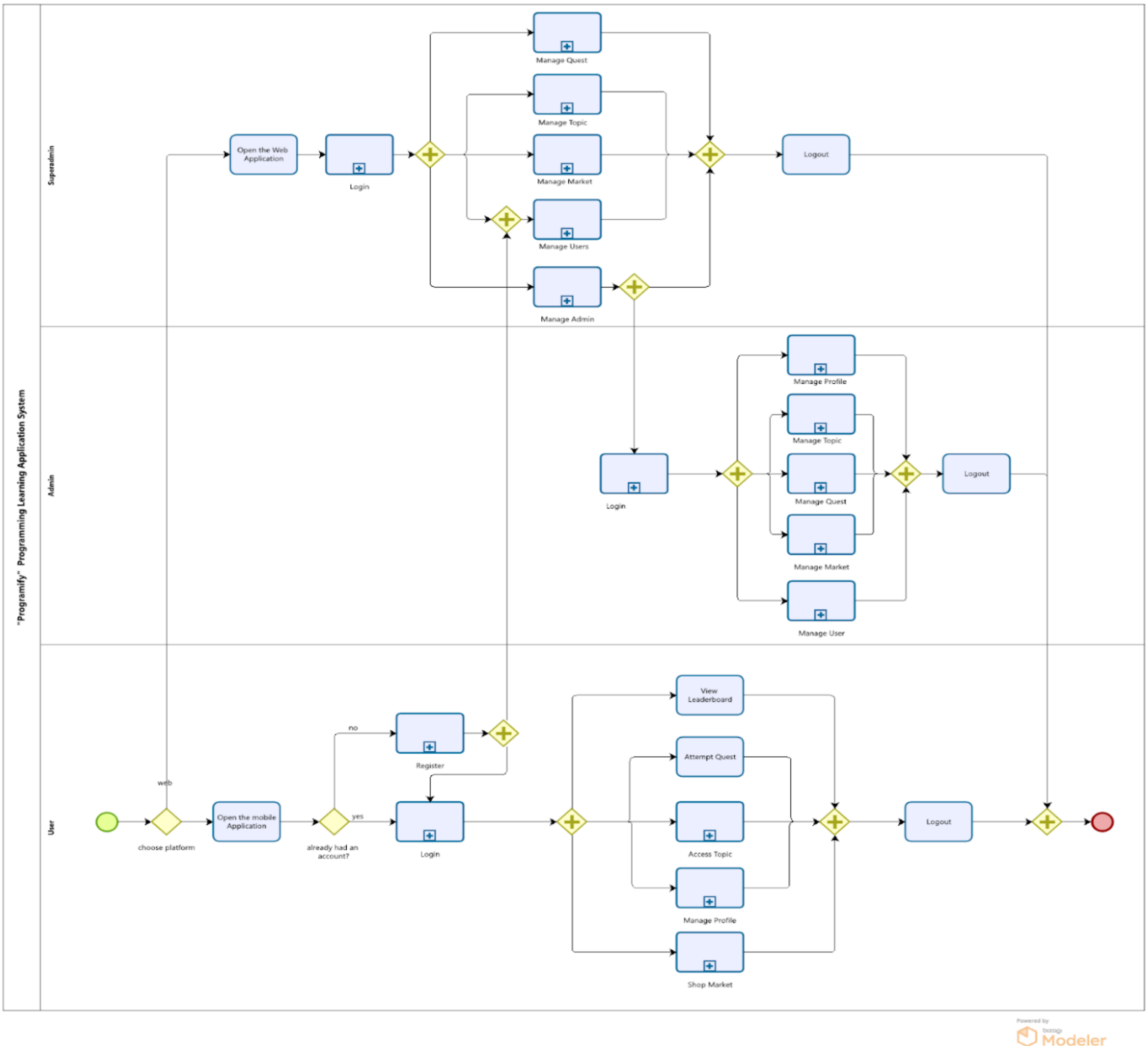

Fig. 4. Business Process Modelling Notation (BPMN)

HMSAM Evaluation

The evaluation model used in this study is the Hedonic-Motivation System Adoption Model (HMSAM), which is designed to assess users' intrinsic motivation in adopting technology systems. HMSAM is an extended framework that integrates key constructs from several well-established models, including the Hedonic Motivation System (HMS), the Technology Acceptance Model (TAM), and the Unified Theory of Acceptance and Use of Technology (UTAUT).

The implementation of HMSAM in this research involved the following steps:

1. Defining Evaluation Objectives

The first step involved identifying the primary goals of the evaluation, such as assessing users' intrinsic motivation, understanding their experience, and evaluating overall system acceptance.

2. Designing the Evaluation Instrument
A questionnaire was developed based on key constructs of HMSAM, including Perceived Usefulness, Perceived Ease of Use, Curiosity, Joy, Control, Behavioral Intention to Use, and Immersion (Fig.). The indicators were adapted from relevant studies to ensure content validity and alignment with the user experience being evaluated, particularly in terms of user motivation and engagement.

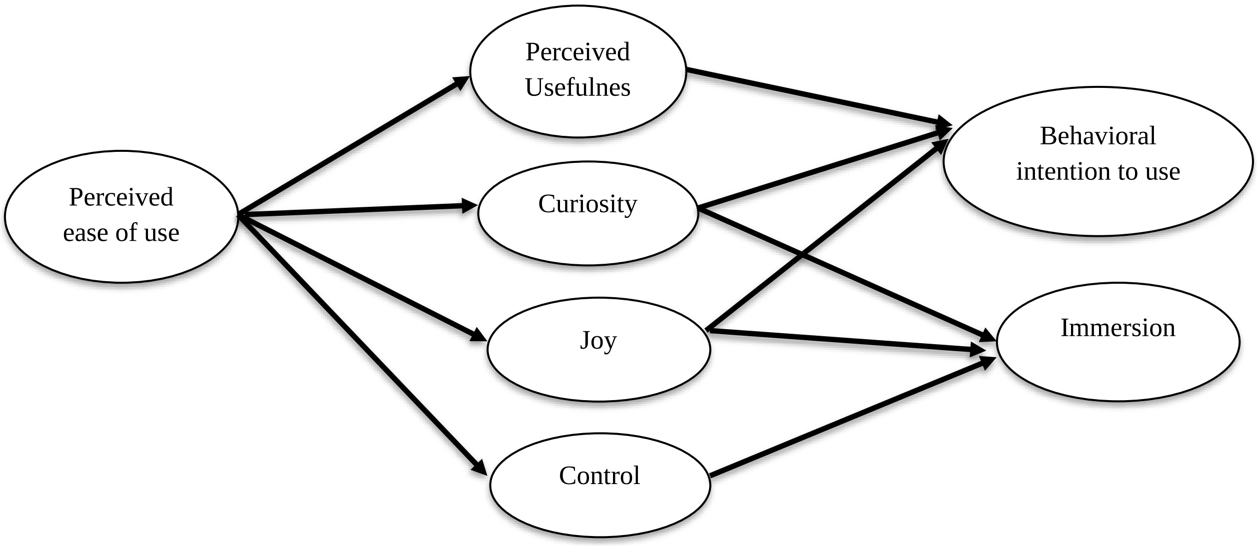

Fig. 5. HMSAM Model

3. Data Collection
Data were collected through structured questionnaires distributed to 116 undergraduate Informatics students at Institut Teknologi Del. The respondents were selected using Slovin's formula. They consisted of first, second, and third-year students (academic years 2022–2024) who were currently taking or had previously completed programming courses. First-year students were enrolled in Functional and Procedural Programming courses, second-year students had taken Basic Programming and Object-Oriented Programming (OOP), while third-year students had applied their programming knowledge in software development projects such as web and mobile applications. The survey aimed to capture students' experiences, perceptions, and responses after use the gamified mobile learning application.

4. Data Analysis
The collected data were analyzed to assess users' intrinsic motivation and engagement using the constructs from the Hedonic Motivation System Adoption Model (HMSAM). Statistical analysis was conducted using SPSS software. The following tools and techniques were applied.
   1. Descriptive Statistics to summarize demographic profiles and survey responses.
   2. Reliability Analysis using Cronbach's Alpha, where a value greater than 0.70 indicates that the items are considered reliable, while a value of 0.70 or below indicates unreliability.
   3. Validity Testing was conducted using Pearson's correlation (Corrected Item-Total Correlation). An item is considered valid if the correlation value exceeds 0.30, and invalid if it is less than or equal to 0.30.
   4. Regression Analysis to evaluate the impact of specific gamification elements on motivation and engagement.

4. Results and Discussions

4.1 Questionnaire Survey

Researchers collected data from 116 first, second and third-year informatics students via a questionnaire that also allowed respondents to provide feedback for mobile app. The feedback was categorized into five main themes: UI/UX improvements, feature development (e.g., notifications, quiz corrections, interactive quizzes), gamification system enhancements (e.g., points, badges, leaderboards), application stability and performance, and additional learning content. Based on this feedback, 11 suggestions related to core functionality and user experience such as navigation button improvements, a leaderboard display, and theme adjustments were successfully implemented. Meanwhile, 12 other suggestions were not pursued. These were rejected because they did not align with the initial system requirements, fell outside the primary scope of the research (particularly non-functional and interface aspects), or required new features beyond the project's scope. However, these suggestions have been noted for consideration in future development.

4.2 Validity and Reliability Test

A validity test was conducted using the Corrected Item-Total Correlation method, where an item was considered valid if its correlation value exceeded 0.3. The results indicated that all items in the research instrument were valid, with correlation values ranging from 0.349 to 0.869. The "Control" construct recorded the lowest correlation (0.349), which, while low, still met the minimum validity threshold. Meanwhile, the "Leaderboard" construct showed the highest correlation (0.869), signifying that its items are a very strong measure of the construct. In conclusion, the findings confirm that the entire questionnaire instrument is valid and reliable for measuring user perception and motivation towards the gamified learning system under study.

Following the validation of all items, a reliability test was conducted to measure the instrument's consistency. The test used Cronbach's Alpha as the coefficient, with a value greater than 0.7 considered reliable. The results showed that all research constructs scored above the 0.7 threshold for Cronbach's Alpha. This indicates that the instrument possesses very good reliability and high internal consistency, meaning the items within each construct uniformly measure the same concept. Therefore, the questionnaire is confirmed to be reliable and suitable for use in the subsequent stages of the research as shown by Table 7.

Table 7 - Validity and Reliability Test Result

No.	Construct	Total Item	Item Correlation Range	Cronbach's Alpha	Status
1	Perceived Ease of Use	4	0.711 – 0.829	0.898	Valid & Reliable
2	Perceived Usefulness	4	0.768 – 0.785	0.899	Valid & Reliable
3	Curiosity	3	0.721 – 0.846	0.893	Valid & Reliable
4	Joy	2	0.761 – 0.761	0.864	Valid & Reliable
5	Control	3	0.349 – 0.693	0.757	Valid & Reliable
6	Immersion	3	0.620 – 0.718	0.808	Valid & Reliable
7	Behavioral intention	4	0.753 – 0.813	0.904	Valid & Reliable
8	Acknowledgement	2	0.740 – 0.740	0.85	Valid & Reliable
9	Point	2	0.824 – 0.824	0.903	Valid & Reliable
10	Stats	2	0.720 – 0.720	0.837	Valid & Reliable
11	Chance	2	0.760 – 0.760	0.864	Valid & Reliable

No.	Construct	Total Item	Item Correlation Range	Cronbach's Alpha	Status
12	Reward	2	0.784 – 0.784	0.878	Valid & Reliable
13	Leaderboard	2	0.869 – 0.869	0.93	Valid & Reliable
14	Objective	2	0.761 – 0.761	0.861	Valid & Reliable
15	Quest	2	0.783 – 0.783	0.878	Valid & Reliable
16	Levelling System	2	0.793 – 0.793	0.885	Valid & Reliable
17	Social Interaction	2	0.822 – 0.822	0.9	Valid & Reliable
18	Progression	2	0.794 – 0.794	0.885	Valid & Reliable
19	Economy	2	0.786 – 0.786	0.88	Valid & Reliable
20	Avatar	2	0.756 – 0.756	0.861	Valid & Reliable
21	Block activities	2	0.807 – 0.807	0.893	Valid & Reliable

4.3 Descriptive Analysis

A descriptive analysis was conducted to evaluate user perceptions of the HMSAM (Hedonic-Motivation System Adoption Model) variables and gamification elements within a programming learning application, using data from a 5-point Likert scale questionnaire. The results revealed an overwhelmingly positive response from users, with all research constructs scoring above 76%, falling within the "agree" to "strongly agree" range.

1. Regarding the HMSAM constructs, Curiosity (85.83%) achieved the highest score, closely followed by Perceived Usefulness (85.26%) and Perceived Ease of Use (84.27%). This indicates that students found the system highly beneficial, curiosity inducing, and easy to use. While the Control (76.55%) construct scored the lowest in this group, its positive rating still suggests it was effective.

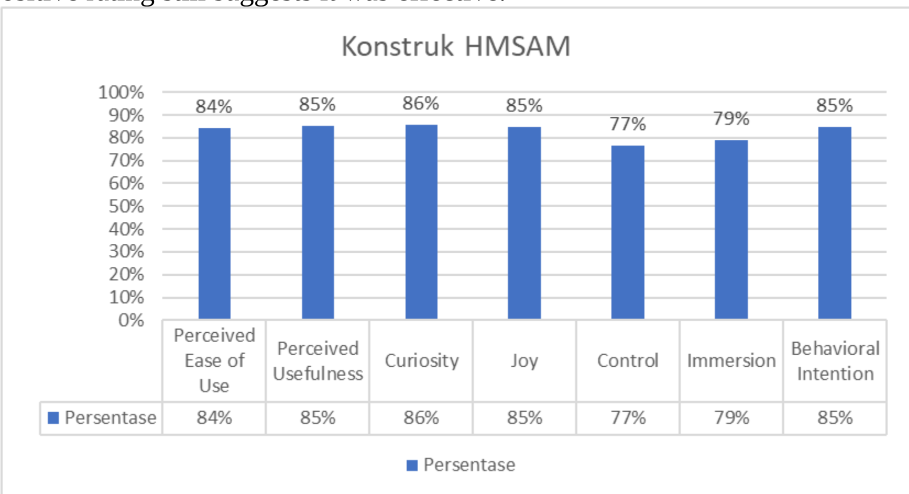

Fig. 6. Descriptive Analysis - HMSAM Construct

2. Among the gamification elements, features like Acknowledgement (84.36%), Points (84.36%), and Quests (84.8%) were rated very highly, proving their effectiveness in motivating users. Other elements, such as Block Activities (82.73%) and Social Interaction (83.45%), while still viewed favorably, scored slightly lower, its positive rating still suggests it was effective.

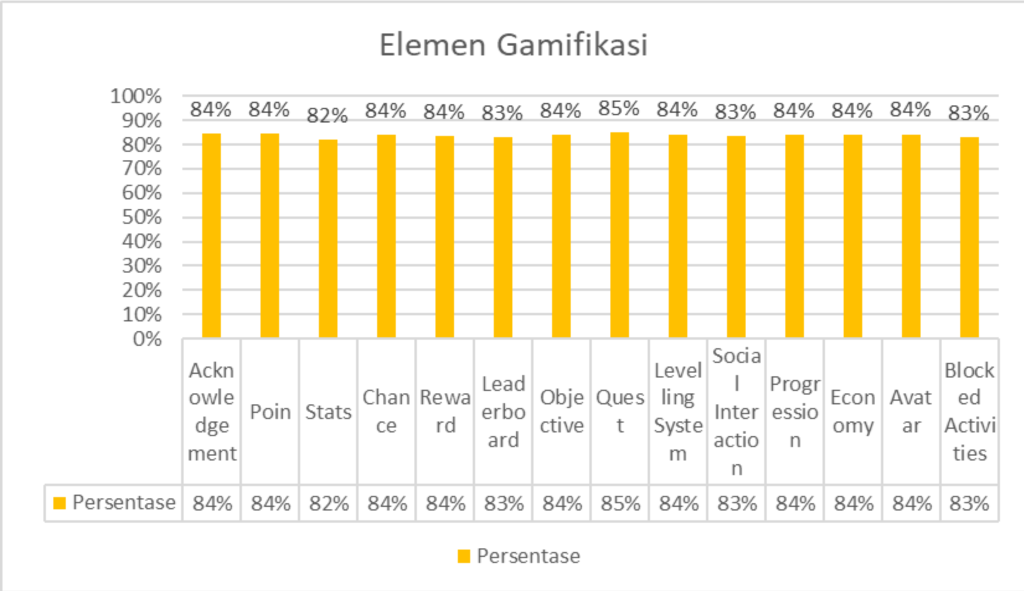

Fig. 7. Descriptive Analysis - Element Construct

Overall, the findings demonstrate that the implementation of gamification positively influenced user perception and engagement. This descriptive analysis provides a foundational understanding that will be further validated through subsequent hypothesis testing. Results and Discussion is a section that contains all scientific findings obtained as research data. This section is expected to provide a scientific explanation that can logically explain the reason for obtaining those results that are clearly described, complete, detailed, integrated, systematic, and continuous.

4.4 Hypothesis Testing Results and Discussion

This section outlines the hypothesis tests designed to address the study's two primary research questions. To address the first research question, the following hypotheses were tested to determine the effect of gamification on student engagement and motivation in learning programming:

1. H_0 (Null Hypothesis): Gamification elements have no effect on student engagement and motivation.
2. H_1 (Alternative Hypothesis): Gamification elements have an effect on student engagement and motivation.

To test this, a multiple linear regression analysis was conducted. The analysis treated the 14-gamification elements as independent variables and student motivation and engagement as the two dependent variables. For the second research question, hypothesis testing was performed to analyze the direction and strength of the relationships between constructs within the Hedonic-Motivation System Adoption Model (HMSAM). The objective was to statistically validate the model's theoretical framework, specifically examining how user perceptions of ease of use, usefulness, curiosity, control, and joy influence their intention and immersion.

Table 8 - HMSAM Hypothesis

No.	Hypotheses
H1	Perceived Ease of Use (PEOU) has an effect on Perceived Usefulness (PU)
H2	Perceived Ease of Use (PEOU) has an effect on Curiosity (CUR)
H3	Perceived Ease of Use (PEOU) has an effect on Joy (JOY)
H4	Perceived Ease of Use (PEOU) has an effect on Control (CTRL)
H5	Perceived Usefulness (PU) has an effect on Behavioral Intention (BI)
H6	Curiosity (CUR) has an effect on Behavioral Intention (BI)
H7	Curiosity (CUR) has an effect on Flow/Immersion (FI)
H8	Joy (JOY) has an effect on Behavioral Intention (BI)
H9	Joy (JOY) has an effect on Flow/Immersion (FI)
H10	Control (CTRL) has an effect on Flow/Immersion (FI)

4.5 Hypothesis Test Results and Discussion (Multiple Regression)

The multiple linear regression analysis shown in Table 9 revealed a highly significant model with an R-Square value of 0.991. This indicates that 99.1% of the variance in student motivation can be explained by the fourteen-gamification elements tested. The model's significance value ($p < 0.05$) confirms that it is statistically significant and suitable for analysis. The results in Fig. show that 12 out of the 14-gamification elements had a significant influence on student motivation. The elements with the highest contribution were Objective ($\beta = 0.112$) and Leaderboard ($\beta = 0.109$). The Quest and Economy elements were not found to be statistically significant predictors of motivation.

Table 9 - Multiple Regression Result - Motivation

No.	Gamification Element	Beta coefficient	Sig. (p-value)	Significant effect
1	Acknowledgement	0.109	<0.001	Yes
2	Point	0.07	0.004	Yes
3	Stats	0.091	<0.001	Yes
4	Chance	0.077	<0.001	Yes
5	Reward	0.081	<0.001	Yes
6	Leaderboard	0.109	<0.001	Yes
7	Objective	0.112	<0.001	Yes
8	Quest	0.03	0.2	No
9	Levelling	0.082	<0.001	Yes
10	Social Interaction	0.081	<0.001	Yes
11	Progress	0.105	<0.001	Yes
12	Economy	0.019	0.331	No
13	Avatar	0.071	<0.001	Yes
14	Block activity	0.08	<0.001	Yes

For the student engagement or immersion variable, the regression model yielded an R-Square value of 0.989, meaning 98.9% of the variance in engagement is explained by the gamification elements, as shown by Fig. . The model was also confirmed to be statistically significant ($p < 0.05$). Similarly, 12 of the 14-gamification elements had a significant influence on student engagement. In this context, Economy ($\beta = 0.141$) and Quest ($\beta = 0.127$) emerged as the most dominant predictors. The Objective and Progress elements were not found to be statistically significant, although the margin was small.

Table 10 - Multiple Regression Result - Engagement

No.	Gamification Element	Beta coefficient	Sig. (p-value)	Significant effect
1	Acknowledgement	0.05	0.04	Yes
2	Point	0.082	0.003	Yes
3	Stats	0.068	0.003	Yes
4	Chance	0.082	<0.001	Yes
5	Reward	0.076	0.004	Yes
6	Leaderboard	0.064	0.002	Yes
7	Objective	0.044	0.079	No
8	Quest	0.127	<0.001	Yes
9	Levelling	0.067	0.004	Yes
10	Social Interaction	0.092	<0.001	No
11	Progress	0.048	0.055	No
12	Economy	0.141	<0.001	Yes

No.	Gamification Element	Beta coefficient	Sig. (p-value)	Significant effect
13	Avatar	0.092	<0.001	Yes
14	Block activity	0.088	<0.001	Yes

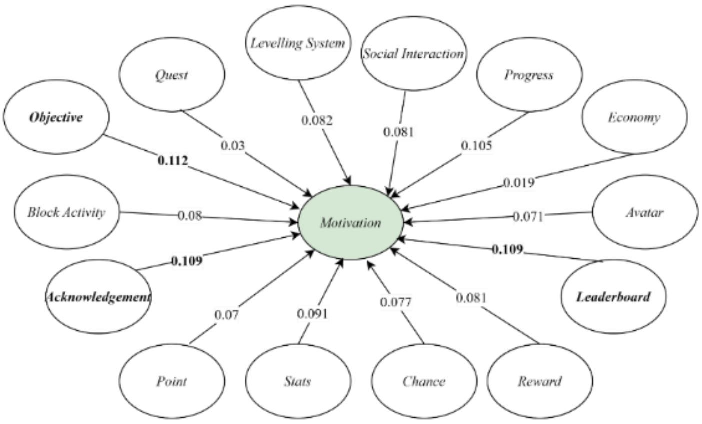

Fig. 8. Multiple Regression - Motivation

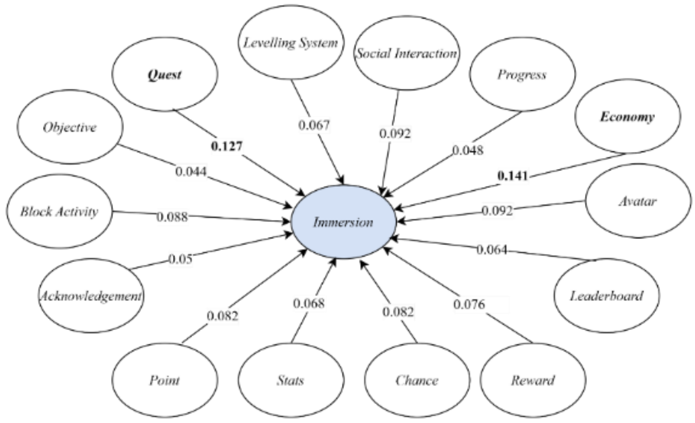

Fig. 9. Multiple Regression - Immersion

Based on this analysis, the alternative hypothesis (H_1) is accepted, and the null hypothesis (H_0) is rejected. The findings confirm that, overall; gamification elements have a significant influence on both the motivation and engagement of students in learning programming.

4.6 Hypothesis Test Results and Discussion (Simple Regression)

This section details the results of the simple linear regression analysis conducted to test the ten hypotheses of the HMSAM. Before presenting the results, the core statistical terms used for interpretation are defined: R (correlation coefficient), R-Square (variance explained), F (F-statistic for model significance), Sig. (p-value), and Beta (standardized coefficient). The primary finding from the analysis is that all ten proposed hypotheses were statistically significant, with significance values (p-values) all being less than 0.001. This confirms a strong and valid relationship between the motivational constructs as defined by the Hedonic-Motivation System Adoption Model (HMSAM).

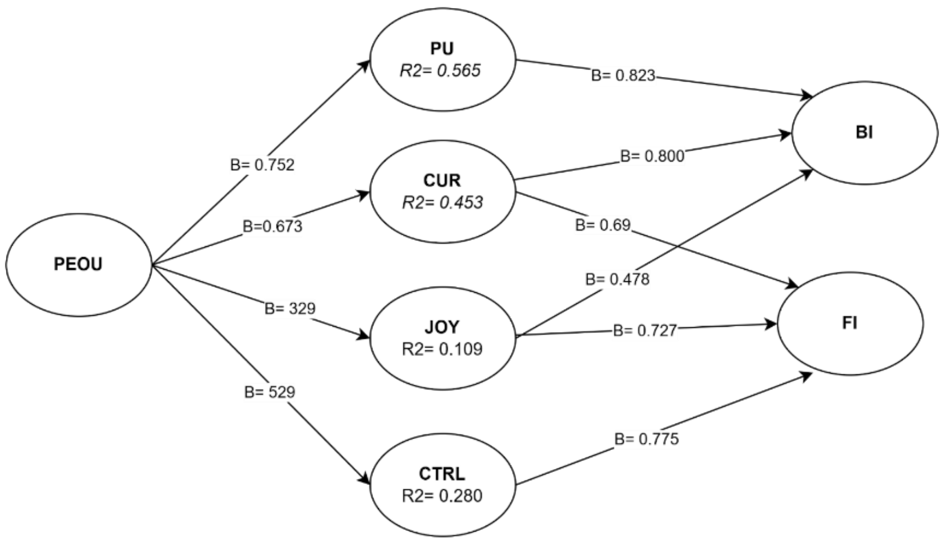

Fig 10. Simple Regression - HMSAM Result

The results of the hypothesis tests confirm that there are strong, significant relationships between the motivational factors (PEOU, PU, CUR, JOY, and CTRL) and the key outcomes of

Behavioral Intention and Flow/Immersion. The findings validate the Hedonic-Motivation System Adoption Model (HMSAM) as an effective framework for explaining user motivation in a hedonically oriented application context. It demonstrates that both utilitarian factors (usefulness, ease of use) and hedonic factors (joy, curiosity, and control) are critical in driving sustained use and deep user engagement.

4.7 Multicollinearity and Common Method Bias Assessment

Variance Inflation Factor (VIF) values ranged from 1.82 to 3.94, remaining below the conservative threshold of 5.0, indicating that multicollinearity among the predictors was not problematic. Additionally, Harman's single-factor test showed that the first factor accounted for 32.4% of total variance, below the 50% threshold, suggesting minimal common method bias. Although the R^2 values were high, diagnostic testing confirmed acceptable predictor independence and minimal bias. The strong explanatory power may be attributed to the integrated multi-layer implementation of gamification within the N-EGM framework rather than statistical overfitting.

4.8 Theoretical Interpretation

The strong effect of Leaderboard and Objective elements can be explained through Social Comparison Theory and Goal-Setting Theory. Leaderboards stimulate competitive comparison, while clear objectives enhance persistence and task commitment. The significant influence of Economy and Quest on immersion aligns with Flow Theory, where optimal challenge-skill balance fosters deep engagement (Hamari et al., 2016). These findings align with Huang et al. (2020), who reported that structured gamification significantly enhances mobile learning engagement, and Bai et al. (2020), who demonstrated stronger effects when multiple gamification elements are integrated. Longitudinal evidence further suggests that gamification may produce sustained improvements in learning performance when integrated systematically rather than applied as isolated mechanics (Sailer & Homner, 2023).

4.9 Comparison with N-EGM Study

The findings of this study demonstrate that the implementation of gamification elements mapped through the N-EGM framework significantly enhances students' motivation and engagement in programming education. These results are consistent with previous research conducted within the NEWTON GAM-LAB project, where the NEWTELP platform received highly positive feedback from students. In that study, the majority of students found gamification to be interesting (over 88%) and reported increased engagement in learning (78%) through features such as points and leaderboards.

Furthermore, the present study expands on these findings by providing more comprehensive quantitative evidence through validity and reliability testing as well as regression analysis. Twelve from Fourteen gamification elements examined were found to have a statistically significant effect on motivation ($R^2 = 0.991$) and engagement ($R^2 = 0.989$), with p-values < 0.005. Additionally, this study demonstrates that mapping gamification elements into the Multi-Layer N-EGM framework including the game-based layer, gamification layer, profiling layer, and socialization layer can produce a gamification design that is not only contextual and effective but also well received by users.

The NEWTON GAM-LAB study also emphasized the importance of learning outcomes, reporting a statistically significant improvement in students' post-test scores compared to pre-test scores, thereby highlighting the cognitive benefits of gamification. While the primary focus of the current study was on motivation and engagement, the results support the notion that increased motivation and engagement are key drivers of improved learning outcomes, as also reflected in the Hedonic Motivation System Adoption Model (HMSAM) used in this study.

In conclusion, this study not only supports prior findings but also extends the understanding of effective gamification design in mobile-based learning environments. The systematic mapping of gamification elements based on their definitions and objectives within the N-EGM framework has proven to be a powerful strategy in creating engaging, meaningful, and sustainable learning experiences for students.

5. Conclusion

Based on the results of the conducted analysis, this study confirms several key findings. First, the evaluation of the research instruments demonstrated strong validity and reliability, as indicated by Cronbach's Alpha values exceeding 0.70 and Corrected Item-Total Correlation scores above 0.30 for all items. These findings suggest that the instrument used to evaluate the gamified application was statistically robust and appropriate.

Second, most of the implemented gamification elements, including acknowledgment, point, reward, leaderboard, leveling, discussion, chance, stats, avatar, and block activity showed consistent significance in enhancing both user motivation ($R^2 = 0.991$) and engagement ($R^2 = 0.989$), with p-values < 0.005. These elements also achieved over 81% in average user approval ratings, indicating a highly positive user perception toward their role in supporting an engaging learning experience.

Third, hypothesis testing for the first research question supported the alternative hypothesis (H_1), demonstrating that the gamification elements significantly influenced student motivation and engagement in programming education ($p < 0.001$). Additionally, all relationships defined in hypotheses 1 through 10 for the second research question were found to be statistically significant ($p < 0.001$), reinforcing that system usability positively contributes to users' curiosity, enjoyment, and behavioral intention to continue using the application.

Finally, the integration of the 14-gamification elements within the N-EGM (Newton-Enhanced Gamification Model) framework proved effective. The alignment of each element to one of the models four layers gamification, game-based learning, profiling and recommendation, and socialization provided a well-structured, contextually relevant, and pedagogically sound design. As measured through the HMSAM model, this approach successfully increased both user motivation and engagement in the mobile learning environment. Despite these promising results, there remain opportunities for improvement. Future studies are encouraged to develop a more advanced automated assessment feature, especially for essay-type questions. Additionally, upcoming research should incorporate user interface (UI) aspects in usability testing to ensure that the application is not only functional but also intuitive and enjoyable for learners to use. This study contributes not only to the empirical validation of the N-EGM framework in a mobile programming education context, but also provides practical design guidance for educators and developers aiming to implement effective and personalized gamification strategies in STEM learning environments.

Theoretically, this study extends gamification research by empirically validating a multi-layer framework integrated with a hedonic adoption model in programming education. Practically, it offers a structured blueprint for adaptive and socially integrated gamification design. Limitations include the single-institution sample, reliance on self-reported measures, and absence of longitudinal analysis. Future research should explore AI-driven adaptive gamification mechanisms supported by intelligent learner modeling and personalized recommendation systems, as recent studies have emphasized the growing role of artificial intelligence in higher education personalization (Al-Samarraie et al., 2023; Manorat et al., 2025).

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