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Developing the Kid-Bright board for controlling lamps and fans as game-based learning for twelfth-grade students

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ABSTRACT

This research aimed to develop and evaluate a gamified learning game using the Kid-Bright board to teach introductory coding skills for controlling lamps and fans to 12th-grade students. The study employed a mixed-methods approach, involving the design and development of the game based on gamification principles, followed by an evaluation by three computer science experts to assess its suitability and effectiveness. The game was then implemented with a sample of 27 randomly selected 12th-grade students from Nong Kungsri Wittayakarn School in Kalasin Province, Thailand. Pre and post-tests were conducted to measure learning outcomes, and a student satisfaction survey was administered to gauge their experience. The findings revealed that the developed game met the 80/80 criterion for efficiency (80.25/84.81), demonstrating its effectiveness in enhancing students' learning progress. The game also received high suitability ratings from experts ($\bar{X}$=4.24, S.D=0.43) and garnered substantial satisfaction from the students ($\bar{X}$=4.78, S.D=0.42), underscoring its potential as an effective and engaging tool for teaching basic coding skills in a real-world context.

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1. INTRODUCTION

In the rapidly evolving digital landscape, education is undergoing a profound transformation, presenting both unprecedented opportunities and challenges for learners worldwide [1]. The acquisition of coding skills has emerged as a critical competency for high school students, equipping them with the tools to navigate and thrive in an increasingly technology-driven world [2]. Recognizing the importance of coding proficiency, Thailand has made concerted efforts to integrate coding into its high school curriculum. However, the instruction of coding faces significant hurdles, including limited access to resources, inadequate teaching methodologies, and a dearth of engaging learning materials specifically tailored for the Thai context [3]. These challenges are particularly pronounced in schools with limited resources, where teachers may lack the expertise and support to deliver effective coding instruction.

To address these challenges, researchers and educators have explored innovative pedagogical approaches, with game-based learning (GBL) emerging as a promising avenue [4]. GBL leverages the inherent appeal of games to create immersive and interactive learning experiences that foster student motivation, engagement, and knowledge acquisition [5]. Scholars have extensively emphasized the potential of GBL and gamification in transforming traditional educational practices, particularly in subjects that may be perceived as

abstract or difficult, such as coding [6]–[10]. By incorporating game elements and mechanics into educational contexts, GBL can make learning more enjoyable, relevant, and effective [4].

One notable GBL platform that has gained traction in Thailand is the Kid-Bright board. Developed by Thai researchers and educators, the Kid-Bright board is an open-source hardware and software platform specifically designed to simplify coding education for novice learners [11]. Featuring a block-based coding environment with graphical blocks supporting both Thai and English languages, the Kid-Bright board makes coding accessible and engaging for Thai students [11]. This innovative platform not only empowers students to develop embedded system projects with ease but also allows educators to create customized learning experiences tailored to the specific needs of their students [12]. The board's affordability and versatility make it an ideal tool for resource-constrained schools in Thailand, where access to expensive software and hardware may be limited.

The integration of the Kid-Bright board into the Thai high school curriculum has the potential to revolutionize coding education in the country. By providing students with a hands-on, interactive, and culturally relevant learning experience, the Kid-Bright board can address the challenges that have hindered the effective instruction of coding in Thai schools. Moreover, the Kid-Bright board's emphasis on real-world applications, such as controlling lamps and fans, can make coding more meaningful and relevant to students' lives, thereby increasing their motivation and engagement [11], [13], [14]. By empowering students to create tangible projects that have a direct impact on their surroundings, the Kid-Bright board can foster a sense of agency and accomplishment, further motivating them to pursue coding as a lifelong learning endeavor.

This research aims to investigate the effectiveness of the Kid-Bright board as a GBL tool for teaching coding to twelfth-grade students at Nong Kungsri Wittayakarn School in Kalasin Province, Thailand. The school has identified a lack of engaging and effective teaching materials for coding education as a significant challenge. To address this issue, this study will develop and implement a GBL curriculum that utilizes the Kid-Bright board to teach students the fundamentals of coding, with a focus on controlling lamps and fans. The study will evaluate the impact of the GBL curriculum on students' coding skills, motivation, engagement, and self-efficacy.

The research will be guided by the systematic instructional design framework of the analysis, design, development, implementation, and evaluation (ADDIE) model, as visually represented in Figure 1 [15]–[18]. The adoption of this model will ensure that the GBL curriculum is precisely tailored to the unique needs of the students and the specific context of the school environment. The study will also integrate and build upon the insights gleaned from previous research on GBL, coding education, and the application of the Kid-Bright board [7], [9], [11].

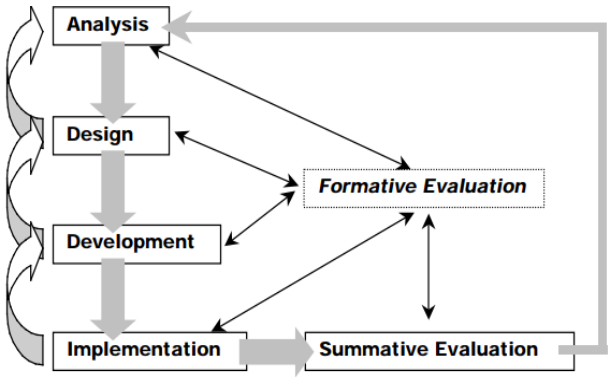

Figure 1. The ADDIE model provides a visual representation of the sequential phases involved in the development of instructional systems

This research is significant in several ways. First, it has the potential to contribute to the body of knowledge on GBL and its application in coding education, particularly in the context of Thailand. Second, the findings of this study could inform the development of more effective coding curricula and teaching materials for Thai high schools, especially those in rural or underserved areas. Third, the research could provide valuable insights into the challenges and opportunities of implementing GBL in resource-constrained settings, which could be applicable to other developing countries facing similar educational challenges. Ultimately, this research aims to empower Thai high school students with the coding skills they need to succeed in the 21st century, thereby contributing to the country's economic and social development.

2. RESEARCH METHOD

This research employed the ADDIE model [19], a systematic instructional design framework encompassing analysis, design, development, implementation, and evaluation phases. The model served as a guide for both the creation and subsequent assessment of the GBL intervention. The primary objective of the study was to ascertain the efficacy of employing the Kid-Bright board as a GBL instrument for imparting fundamental coding skills related to the control of lamps and fans to 12th-grade students. This methodological approach ensured a structured and comprehensive investigation into the potential of GBL and the Kid-Bright board in enhancing coding education.

2.1. Participants

The research participants were 27 twelfth-grade students from Nong Kungsri Wittayakarn School in Kalasin Province, Thailand. This sample size was determined based on Krejcie and Morgan's [20] table, which suggests a sample size of 27 for a population of 155 to achieve a confidence level of 95% and a margin of error of 5%. The participants were randomly selected from a single classroom using a lottery method to ensure representativeness and minimize bias. The focus on a specific classroom allowed for a more controlled and focused study, enabling in-depth insights into the effectiveness of the GBL intervention.

2.2. Research instruments

The research utilized the following instruments:

- Game-based learning platform utilizing the Kid-Bright board: a gamified learning game was developed to teach basic coding skills related to controlling lamps and fans. The game was designed to be engaging and interactive, incorporating various game elements and mechanics to enhance student motivation and learning. The game underwent a thorough evaluation by three domain experts in computer science to ensure its accuracy, appropriateness, and overall quality as a learning tool. The experts rated the game on various aspects, including game design, visual appeal, menu organization, engagement, clarity of game steps, game difficulty, gameplay dependency on players' abilities, duration of gameplay, players' use of thinking skills, benefits gained from playing the game, and awareness of game objectives.
- Learning effectiveness index (E.I.) test: a pre-test and post-test design was employed to measure the effectiveness of the GBL intervention. The pre-test consisted of 10 multiple-choice questions, and the post-test consisted of a 10-point assessment. The tests assessed students' coding skills and their ability to control lamps and fans before and after engaging with the game. This allowed for a quantitative evaluation of the impact of the intervention on student learning outcomes using the E.I.
- Student satisfaction questionnaire: a 5-point Likert scale questionnaire was administered to gauge students' satisfaction and engagement with the learning game. The questionnaire sought feedback on various aspects of the game, including its design, content, usability, and overall learning experience. This provided valuable insights into students' perceptions and attitudes towards the GBL approach.

2.3. Data collection procedure

Data collection occurred in the second semester of the 2022 academic year. Before gameplay, a pre-test was administered to assess baseline coding knowledge. Students then engaged with the GBL platform for a duration of 1 hour. Following the intervention, a post-test was administered to evaluate learning gains. Additionally, students completed the satisfaction questionnaire to provide feedback on their experience.

2.4. Data analysis

The data collected from the pre-test and post-test were analyzed using an effectiveness index (E.I.) to quantitatively measure the impact of the GBL intervention on the students' coding skills and their ability to control lamps and fans. The E.I. provides a standardized metric to assess the extent of learning gains achieved through the intervention. In addition to the quantitative analysis, the student satisfaction questionnaire data were analyzed using descriptive statistics, including means and standard deviations. This analysis aimed to gain a deeper understanding of the students' subjective perceptions and attitudes toward the game, offering valuable insights into their overall learning experience and engagement with the GBL approach.

3. RESEARCH FINDINGS

This section presents the key findings of the study, focusing on the development and implementation of the Kid-Bright Board as a game-based learning (GBL) tool for teaching coding skills to 12th-grade students. The results are organized into three distinct subsections: the utilization of the Kid-Bright Board as a GBL platform, a comprehensive evaluation of the GBL approach itself, and an assessment of both learning

effectiveness and student satisfaction. This multifaceted analysis provides a holistic understanding of the impact and potential of the Kid-Bright Board as an educational tool within the context of GBL.

3.1. Utilization of the Kid-Bright Board as a game-based learning platform

The Kid-Bright board was effectively utilized as a GBL platform for controlling lamps and fans. The development of a gamified learning experience using the Kid-Bright board aimed to integrate learning and enjoyable gameplay for twelfth-grade students. As depicted in Figure 2, the game encompassed various components, including login and welcome pages, objectives, pre-learning quizzes, Kid-Bright content, board usage tutorials, task sheets, challenge instructions, game item introductions, component descriptions, game rules, button guides, level selections (ranging from levels 1 to 7), gameplay scores, Kid-Bright board functionality, post-learning quizzes, menus, and information about the developers. These components were meticulously designed to provide students with an engaging learning experience aligned with the principles of GBL [21], [22]. For instance, the pre-learning quizzes assess prior knowledge and prepare students for the subsequent content, while the board usage tutorials provide step-by-step instructions on how to use the Kid-Bright board to control lamps and fans. The inclusion of multiple levels gradually increases the complexity of coding tasks, allowing students to build upon their skills progressively.

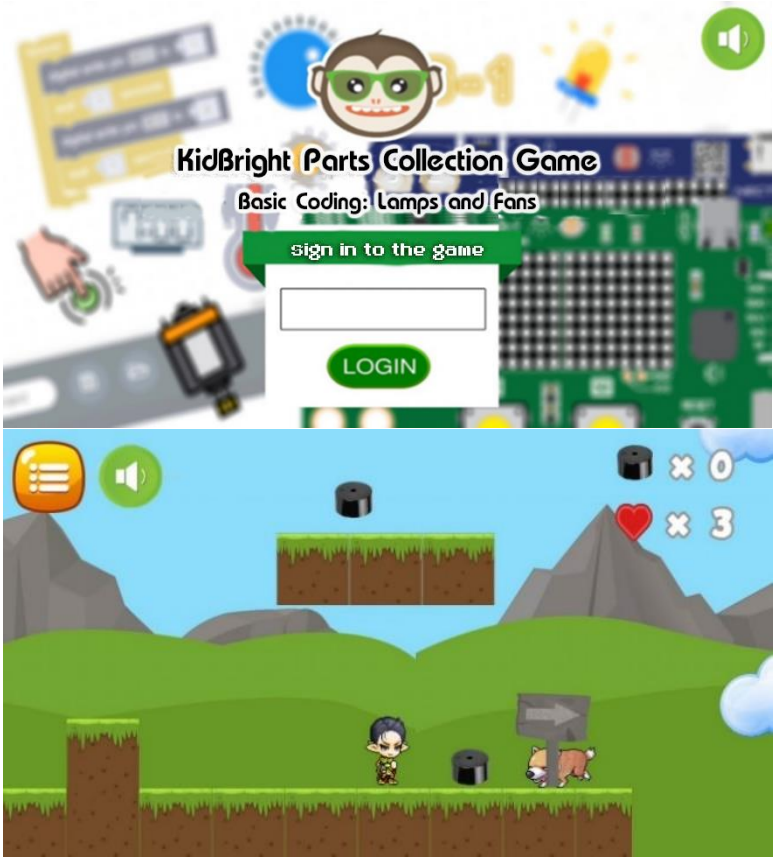

Figure 2. Game interface for learning introductory coding, lamps, and fans using the Kid-Bright board

3.2. Evaluation of the game-based learning approach

The GBL approach using the Kid-Bright board for controlling lamps and fans underwent a comprehensive evaluation by three experts in computer science and technology education. The experts were selected based on their extensive experience in GBL and their knowledge of the Kid-Bright board. The evaluation criteria included game design, visual appeal, content accuracy, pedagogical effectiveness, and overall user experience. The evaluation results indicated that the approach is highly suitable for twelfth-grade students. Experts provided positive ratings for various aspects of the game, including design, visual appeal, menu organization, engagement, clarity of game steps, game difficulty, gameplay dependency on players' abilities, duration of gameplay, players' use of thinking skills, benefits gained from playing the game, and

awareness of game objectives. Nevertheless, certain areas, such as aesthetics, game difficulty, player-dependent gameplay, and cognitive engagement, were identified as potential areas for improvement.

Regarding typeface suitability, experts expressed high satisfaction, particularly in conveying meaning, typeface selection, font size, and font color. The assessment of the game itself, including the clarity of instructions, consistency with the game content, appropriateness of questions, and reporting of test scores, also received high ratings. The game development format, encompassing learning outcomes, significant concepts, storytelling, learning activities, teamwork, and game mechanics, was evaluated as highly suitable [21], [22].

3.3. Evaluation of learning effectiveness and student satisfaction

The study evaluated the learning effectiveness and student satisfaction with the GBL approach using the Kid-Bright board for controlling lamps and fans among 27 twelfth-grade students. The learning E.I., calculated based on pre- and post-class scores, as shown in Table 1, indicated a significant academic improvement among students, with a score of 0.77 or 77%. This demonstrates a notable enhancement in learning outcomes for twelfth-grade students. The satisfaction survey results, presented in Table 2, showed high overall satisfaction among students regarding the development of the Kid-Bright board as a GBL tool for controlling lamps and fans. Students expressed high satisfaction with content presentation, button placement, background music, study duration, knowledge gained, engagement in the storyline, game soundtrack, and ease of assessment use [21], [22].

Table 1. Evaluation of the learning E.I. of the GBL approach using the Kid-Bright board

Testing	Sample group (N)	Full score	Average score	E.I. (%)
During class activities (E1)	27	90	72.22	80.25
Post-learning assessment (E2)	27	10	8.48	84.81

Table 2. Evaluation of student satisfaction with the development of the Kid-Bright board as a GBL tool for controlling lamps and fans

Evaluation list	$\bar{x}$	S.D.	Appropriateness level
1. Game design			
– Visual appeal	4.00	0.00	High
– Menu organization	4.33	0.58	High
– Engagement	4.67	0.58	Very high
– Clarity of game steps	4.33	0.58	High
– Game difficulty	4.00	0.00	High
– Gameplay depends on player's abilities	4.00	0.00	High
– Duration of gameplay	4.33	0.58	High
– Players' use of thinking skills	4.00	0.00	High
– Benefits gained from playing the game	4.67	0.58	Very high
– Awareness of the game's objectives	4.67	0.58	Very high
Average per aspect	4.30	0.35	High
2. Appropriateness of font usage			
– Appropriateness in conveying meaning	4.00	0.00	High
– Appropriateness of typeface	4.33	0.58	High
– Appropriateness of font size	4.33	0.58	High
– Appropriateness of font color	4.33	0.58	High
Average per aspect	4.25	0.43	High
3. Test assessment			
– Clarity of instructions	4.33	0.58	High
– Consistency between the test and content	4.33	0.58	High
– Appropriateness of questions	4.33	0.58	High
– Appropriateness of answer choices	4.33	0.58	High
– Reporting test scores	4.67	0.58	Very high
Average per aspect	4.40	0.58	High
4. Game development format			
– Identification of learning outcomes	4.00	0.00	High
– Selection of significant concepts	4.00	0.00	High
– Game storyline	4.00	0.00	High
– Design of learning activities	4.00	0.00	High
– Team formation	4.00	0.00	High
– Application of game mechanics	4.00	0.00	High
Average per aspect	4.00	0.00	High
Overall average	4.24	0.43	High

In summary, the research findings indicate the successful utilization of the Kid-Bright board as a GBL platform for controlling lamps and fans among twelfth-grade students. The GBL approach using the Kid-Bright board was highly suitable and effectively improved learning outcomes. The findings also highlight high levels of student satisfaction with various aspects of the game. These results contribute to the growing body of evidence supporting the effectiveness of GBL in enhancing student engagement and academic achievement, particularly in STEM fields. Further research could explore the long-term impact of this approach and its applicability to other subject areas.

4. DISCUSSION

The integration of GBL with the academic curriculum, particularly in the context of controlling lamps and fans using the Kid-Bright board, has proven to be a successful approach. The gamification approach, as implemented in this study, significantly enhanced the learning process, making it more engaging, interactive, and enjoyable for students [23]–[26]. This is consistent with the findings of previous research, which found that integrating GBL with academic content can lead to increased student motivation and engagement [27], [28]. The various components of the developed game, such as the login page, objectives page, content pages, tutorial videos, and level progression, were meticulously designed to provide a seamless and immersive learning experience, thereby facilitating the acquisition of knowledge and skills related to lamps and fans [29]. This aligns with Robertson and Woods's [30] principles of good learning principles in video games, which emphasize the importance of active, critical learning, design, and well-ordered problems.

The effectiveness of this GBL approach is further supported by the research findings, which indicate a significant improvement in academic performance, as evidenced by higher average scores in in-class exercises and post-learning assessments. This result aligns with the conclusions of previous research [31], [32], which found that GBL approaches can lead to improved learning outcomes in educational settings. The GBL approach successfully met the predefined criteria for effectiveness, demonstrating its potential as an innovative educational tool that can significantly enhance student learning and engagement [31], [32]. These findings also echo the sentiments in previous research [25], which propose that the success of GBL lies in its ability to foster a sense of achievement and motivation among students through game elements like challenges, levels, and scoring.

The positive ratings received from the evaluation of the GBL approach by experts in computer science and technology education further validate its effectiveness. The experts expressed overall satisfaction with various aspects of the game, including its design, visual appeal, clarity of instructions, alignment with content, and reporting of test scores [24]. This feedback aligns with the findings of previous research [24], which highlighted the importance of intelligent game design in improving students' problem-solving abilities. However, the experts also identified areas for improvement, such as aesthetics, game difficulty, player-dependent gameplay, and cognitive engagement. These suggestions provide valuable insights for refining and enhancing the game design to optimize the learning experience and address specific challenges. The iterative nature of the ADDIE model [33] allows for continuous improvement and refinement of the game based on expert and user feedback.

The high student satisfaction ratings underscore the potential of GBL to foster a positive attitude towards learning and increase motivation among students [34], [35]. The positive feedback on aspects such as content presentation, button placement, background music, and knowledge gained indicates that the game effectively engaged students and facilitated their learning experience. This is consistent with the meta-analysis by Hu and Razlo [36], which found a positive correlation between GBL and student achievement. The findings also support the idea that GBL can cater to diverse learning styles and preferences [8], [37]–[39]. The high satisfaction levels reported in various aspects of the game highlight the effectiveness of the game in engaging students and facilitating their learning experience.

In conclusion, the development and utilization of the Kid-Bright Board as a GBL tool for controlling lamps and fans offer promising opportunities for enhancing twelfth-grade education. The integration of game elements with academic content effectively promotes learning outcomes and student engagement. Future research should focus on refining the game design based on the feedback received from experts and students, addressing the identified areas for improvement, and exploring the potential of GBL in other subject areas. Additionally, further research could investigate the long-term impact of this approach on students' learning and retention of knowledge and skills [40]–[42]. The findings of this study contribute to the growing body of evidence supporting the effectiveness of GBL in enhancing student engagement and academic achievement, particularly in STEM fields [43], [44], and provide valuable insights for educators and researchers interested in implementing GBL in their own contexts.

5. CONCLUSION

In conclusion, this research study successfully developed and implemented a gamified learning game using the Kid-Bright board to teach introductory coding skills for controlling lamps and fans to 12th-grade students in Thailand. The GBL approach effectively integrated game elements and mechanics into the learning process, creating an engaging and interactive experience that resulted in a significant improvement of 77% in learning outcomes. The evaluation by computer science experts confirmed the game's suitability and effectiveness as a learning tool, meeting the 80/80 criterion for efficiency. Furthermore, the game received high satisfaction ratings from students, with an average rating of 4.78 out of 5. These results highlight the potential of the Kid-Bright board as a valuable tool for enhancing coding education in Thailand, particularly in schools with limited resources. The emphasis on real-world applications, such as controlling lamps and fans, not only makes coding more meaningful and relevant to students' lives but also increases their motivation and engagement, fostering a sense of agency and accomplishment. This research contributes to the growing body of evidence supporting the effectiveness of GBL in enhancing student engagement and academic achievement, particularly in STEM fields. Future research should focus on the long-term impact of GBL interventions, explore the adaptability of the Kid-Bright board to other subjects and learning objectives, and investigate its potential for fostering computational thinking and problem-solving skills among Thai students. The insights gained from this study can inform the development of more effective and engaging coding curricula, ultimately empowering Thai high school students with the coding skills necessary for success in the 21st century.

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