Pertanika J. Soc. Sci. & Hum. 32 (2): 387 - 407 (2024)

PERTANIKA JOURNALS

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Case Study

The Application of an Unplugged and Low-Cost Children's Coding Education Tool in a Gamification Context

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ABSTRACT

Coding education has become a compulsory course for cultivating children's computational thinking, and its tools in a gamification context can further enhance children's learning enthusiasm. Through the literature review, the researchers identified gamification, unplugging, and low cost as important design requirements for children's coding education tools. In order to verify the effectiveness of teaching design, this study specially developed a gamified coding education tool, "Coding Adventure," which allows child learners to take on gamified roles in real-life scenarios and use instruction cards to complete tasks. While testing the prototype in the on-site teaching environment, the researchers invited 12 kindergarten and elementary school teachers to observe the testing process. Then, they formed a focus group discussion to obtain their feedback on the education tool using MAXQDA software for qualitative analysis. According to the results, teacher participants generally recognize the design concepts of gamification, unplugging, and low-cost, and believe that role-playing and rewards in gamification, as well as the use of safe and simple materials to match the existing teaching environment of the school, are successful design innovations. In addition, gamified storytelling has also been proven to enhance students' team communication using this prototype. Overall, this study proves the effectiveness of the design concepts of gamification, unplugged and low cost on the perceived usefulness and ease of use of the coding education tool

ARTICLE INFO

Article history:
Received: 13 July 2023
Accepted: 31 January 2024
Published: 10 June 2024

DOI: https://doi.org/10.47836/pjssh.32.2.03

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ISSN: 0128-7702
e-ISSN: 2231-8534

system under the Technology Acceptance Model theory framework. These student-centered design concepts will provide valuable experience for the further development of unplugged coding education tools.

Keywords: Coding education, gamification, low-cost, role-playing, reward, unplugged

INTRODUCTION

Computational thinking has become essential to adapt to the globalization of information based on data products and services (Vyas, 2022). Correspondingly, coding education that cultivates computational thinking has become a prominent feature of modern international education courses to ensure students can deal with complex, open-ended, and unusual problems in the future (Zhao et al., 2022). When coding education was added to school curricula, it significantly boosted computational thinking in children (Özcan et al., 2021). As a result, children's coding courses, such as enlightenment courses for mathematics and logic teaching in kindergartens and primary schools, are gradually valued by China's education sector (Fu et al., 2023). As a result, coding education in China directly influenced students' interest in science, technology, engineering, and mathematics (STEM) careers (Jiang et al., 2022).

Gamification holds great promise for extending the gaming experience and enhancing user motivation for coding applications (Heljakka et al., 2019). Gamification-based learning occupies an important position in the curriculum system that uses coding teaching to realize computational thinking training (Israel-Fishelson & Hershkovitz, 2022). Gamification uses game-specific design elements in non-game contexts (Sanchez et al., 2020). Integrating gamification into coding project development courses has proved to have a good effect, and most students support coding teaching in the form of gamified flipped classrooms (Hasan et al., 2018).

Additionally, previous research has demonstrated that combining coding and gamification to form an augmented pedagogy can stimulate children's mathematical talents and prepare them for further exposure to artificial intelligence and robotics (Folgieri et al., 2019). The rapid advancement of technology has brought significant changes to the field of education, and the original teacher-centered coding education has gradually transformed into a student-independent education process (Hasan et al., 2018). In the existing coding courses, designers use toy robots as carriers to teach children to design tracks, solve obstacles, and use gamification competitions to motivate participants (Heljakka et al., 2019), which brings inspiration to this study.

However, the issue of whether children's cognitive mental health is affected during the popularization of gamification elements in coding courses is still controversial (Kamarudin et al., 2022). Performance hits and leaderboard-induced negativity

are the most common negative effects of gamification elements in education (Toda et al., 2018). In addition, the addiction problem caused by using gamification in electronic applications has gradually been paid attention to (Schöbel et al., 2021). The high investment in electronic equipment is also considered a hindrance to the realization of the coding curriculum (Brackmann et al., 2019). Therefore, using an unplugged design in primary coding lessons should be fully considered to avoid children's addiction to electronic applications.

In order to verify the impact of technology adoption on teaching effectiveness, the TAM theory is considered to show a good explanatory effect (Scherer et al., 2019). In a case study of teachers' adoption of information and communication technology for teaching, perceived ease of use and usefulness in the TAM theory positively affected primary school teachers' continuance intention to use (Bai et al., 2021). Especially when facing the application of new technologies, TAM theory shows good explorability for new application environments (Amron & Noh, 2021). Therefore, this study applied TAM theory to understand teachers' views on the perceived ease of use and perceived usefulness of coding education tools that incorporate new design ideas.

In summary, the research objective of this study is to prove the effectiveness of the design concepts of gamification, unplugged, and low cost on the perceived usefulness and ease of use of the coding education tool system under the framework of the TAM theory. In addition, this study also hopes to further understand which specific design technologies can optimize the gamification, unplugged, and low cost of the education tool. To achieve this objective, a coding education prototype that is gamified, unplugged, and low-cost will be designed to obtain valuable feedback from educators.

LITERATURE REVIEW

Adding gamification mechanisms to educational environments to motivate student learning behavior and promote student motivation to solve problems has proven to have high applicability (Klock et al., 2020; Krath et al., 2021). For enhanced learning, virtual elements in gamification mechanisms, including storytelling and character narrative, can effectively enhance students' learning experience (Sailer & Homner, 2020). Furthermore, various elements in the gamification mechanism are proven effective in improving student learning motivation, especially the reward system with badges, points, and leaderboards as the core (Bovermann & Bastiaens, 2020). In addition, story-based gamification is proven to enhance Chinese students' sense of belonging in coding courses (Cao, 2023). Therefore, in designing interactive tools for the digital age, non-linear narrative techniques such as role-playing games and interactive activities can be used in computational thinking teaching and learning tools (Campos et al., 2019).

In addition, gamification effectively integrates teamwork, communication with people, self-exploration, information

acquisition, comprehensive analysis and other applied knowledge and the ability to carry out work to adapt to the development of the new environment into practical applications (Murillo-Zamorano et al., 2021). Allowing students to calculate point rewards on an individual and team basis in gamification-based learning can effectively promote their sense of competition and teamwork skills (Kerestes et al., 2021). Gamified rewards (points, trophies, and rankings) can effectively motivate students' negative emotions in coding learning, thereby prompting students to maintain good motivation in long-term learning (Zatarain Cabada et al., 2020). All gamification mechanisms must be considered when designing the test prototype and conducting focus group discussions.

When it comes to gamification, the public generally associates it with computer-related activities, but gamification can also enable "tangible" and "unplugged" interactive experiences through visual activities and constructivism (Huang & Looi, 2021). Previous research has shown that tangible coding games are more acceptable to children than virtual online game mechanics (Madariaga et al., 2023). Unplugged coding instruction can be implemented by properly organizing children's classroom activities to improve their problem-solving skills, including building healthy relationships with friends, understanding the emotions of those around them, and seeing problems from other people's perspectives (Hufad et al., 2021). As a result, the children are excited and enthusiastic about the preparation and progress of the gamification activities and can fully respond to the teacher's interaction (Hufad et al., 2021). It also strengthened our determination to design physical coding games.

On the other hand, designers must pay attention to and define the needs of students before adding gamification elements to coding projects to enhance the effect of gamification (Gui et al., 2019). Incorporating gamification into the course experience must also incorporate a "student-centered" approach, which requires an ongoing investment in prototyping and testing (Venkatesh et al., 2021). Therefore, adhering to human-centered prototyping and keeping iterations low-cost has proven necessary for many educational technologies, from development to final solution (Tseng et al., 2019). The tangible coding tools designed for children are expensive or can only achieve predetermined functions (Im & Rogers, 2021). Therefore, using cheap items to create tangible interfaces has become the focus of researchers hoping to make breakthroughs (Im & Rogers, 2021). It is also an important reason why the researchers considered students' feelings more in the design and paid attention to cost control.

As computational thinking and coding elements are gradually added to primary school curricula, the teaching effect of these skills has a positive impact on children's cognitive development, especially on behavioral executive functions (Arfé et al., 2020). Coding courses allow children to learn new ways to express themselves and expand their cognition, language, and

social emotions (Papadakis, 2021). In order to expose younger children to coding education, unplugged coding activities use physical instruction sets to give children the opportunity to understand elementary coding logic (Lee & Junoh, 2019). The unplugged teaching model also has the characteristics of convenient and quick deployment and management, making it easier for teachers to prepare for teaching. It also allows teachers to assess learners' abilities (Relkin et al., 2020).

Although coding education for children has become popular, there is still a lack of consensus on teaching feedback and evaluation standards (Alves et al., 2019). For children's coding education, teachers do not necessarily need high confidence in their computing or programming abilities to teach well (Rich et al., 2019). As computing and coding abilities become increasingly important in future jobs, coding education also takes on the task of helping teachers overcome concerns about teaching computers (Rich et al., 2019). In coding education, teachers can use the instructional environment of coding and computational thinking as a playground, combined with art, music, and social studies, to demonstrate autonomy for classroom communication, collaboration, and creativity (Bers et al., 2019). Using low-cost materials to develop practical and interactive teaching resources can help schools and teachers promote coding teaching more conveniently (Yeboah et al., 2019). Additionally, knowledge about teaching programming can enhance teachers' self-efficacy, pedagogical knowledge, and attitudes (Mason & Rich, 2019).

To sum up, for coding education tools designed for young children, developers need to add gamification to increase its fun, use unplugged design to enhance interaction, protect children's health, and ensure low cost to increase popularity efficiency (Chen et al., 2023). Therefore, unplugged board games and building blocks that combine the above three elements became the design plan for this study (Chen et al., 2023). Adopting such a design plan is a balancing consideration of three aspects: children's cognitive patterns, parents' health concerns, and educators' costs.

Theoretical Foundation and Hypotheses

This study used the TAM theory first proposed by Davis (1985) and simplified it according to the requirements for this test. In the subsequent studies of Davis (1989) and (1993), perceived usefulness and ease of use were determined to judge the user's acceptance of the system. In this study, the perceived usefulness and perceived ease of use of the coding education tool by teacher users were used as the independent variables, and the actual system use of the tool they observed was used as the dependent variable to simplify the previous mature theoretical model (Venkatesh & Davis, 1996). Therefore, this study draws the following theoretical framework (Figure 1).

In the case study of TAM theory, gamification showed extremely high perceived usefulness and ease of use in higher education teacher training and effectively promoted learners' continuance intentions (Vanduhe et al., 2020). In a

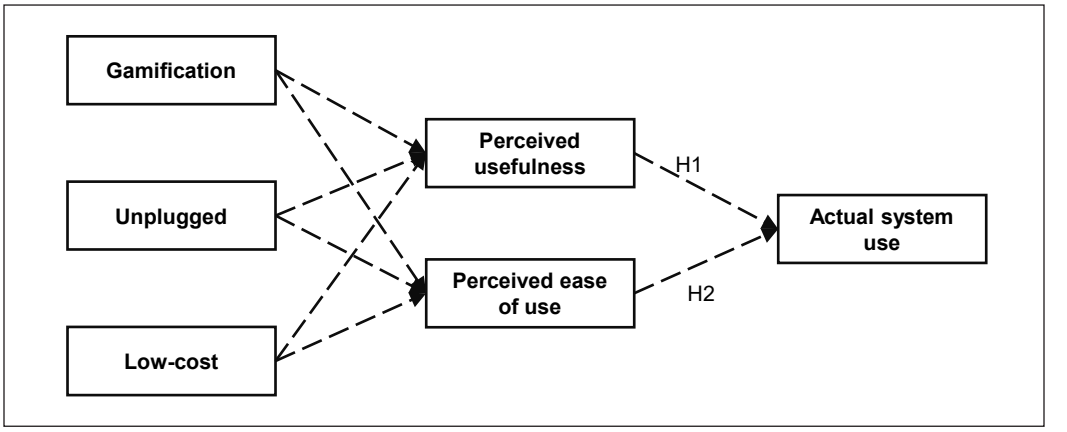

Figure 1. Theoretical framework of this study
Source: Authors' work

similar case with secondary school students, using the coding system of unplugged flowblocks can effectively improve students' sense of self-efficacy and make teachers feel the usefulness of this teaching method (Threekunprapa & Yasri, 2020). Gamification and low cost have been proven to increase the usability of remote robot programming teaching tools and have a better promotion effect than traditional physical robots (Kiliç & Gökoglu, 2022). According to the above literature review, this study takes gamification, unplugged and low-cost as the core of the problem for measuring independent variables to test the rationality of the above framework, so the following two hypotheses are drawn:

H1. The children's coding education tool, under the influence of gamification, is unplugged and low-cost, provides sufficient perceived usefulness for educators, and finally affects the actual use of the system.

H2. The children's coding education tool, under the influence of gamification, is unplugged and low-cost, provides sufficient perceived ease of use for educators, and finally affects the actual use of the system.

Based on the theoretical framework and in line with the research objectives, the researchers of this study summarized the key points of the test prototype design and focus group discussion in Table 1.

METHODOLOGY

The researchers examined the existing coding education tools on the market. They found that they could not meet the research objectives and design requirements simultaneously, and some were copyrighted and could not be used publicly. Therefore, the researchers decided to use self-designed tools as study instruments.

Based on the design solutions obtained from the literature review and market demand, the researchers developed a gamified coding education tool called "Coding Adventure." This educational tool has an interesting backstory: the

Table 1
Design points and focus group questions summarized after the literature review

Literature review highlights	Test design objectives	Focus group discussion questions
Incorporation of Gamification Elements	Storytelling, Role-Playing, Rewards, Team Communication	Through this test, how do you feel about adding the gamification elements of the game story and role-playing to the test prototype? From your observations, how do you think the students reacted to the rewards and team communication during the test? Did it meet your expectations?
Unplugged and Realization	No Electronic Equipment, Use Existing Teaching Environment	What are your thoughts on designing without electronics in test prototypes? Is the test prototype a reasonable use of the teaching environment? Do you have any suggestions?
Student-Centered, Low-Cost Iteration	Encourage Group Participation, Use Readily Available and Low-Cost Tools	What do you think of the effect of the collective participation of the students in this test? What kind of improvement can we get? Do you think the low-cost tools used in this test prototype are suitable? Any suggestions?

Source: Authors' work

story of a brave knight who overcomes obstacles, destroys monsters and saves his friends. This backstory is told to child participants before starting the level to enhance immersion. Child participants who use this tool play the role of a knight. He/She can receive instruction cards by setting an exploration path in advance and placing these cards while crossing each map grid. The gamification task of this tool is to travel across the map, find treasures or defeat monsters. Child participants must use computer thinking to predict all possible events and set coding commands in advance.

In order to reduce costs and facilitate recycling for future use, all the maps in this learning tool are made of foam splicing boards, and the game items are made of foam and sponge materials. In addition, child participants are provided with soft-material armor, weapons and items to simulate real operations. These props also use low-cost and recyclable materials and ensure sufficient safety. The learning process involves students selecting paper cards, planning adventure routes, and completing gamified tasks. "Coding Adventure" supports single-player and multiplayer modes. In multiplayer mode, several students must communicate and cooperate to complete the task (Figure 2).

After the "Coding Adventure" test prototype was completed, the researchers invited a class of kindergarten students to take a one-hour test. After obtaining consent from parents, students, kindergarten leaders, and teachers, the researchers explained the rules of the gamified tool to the students and guided them through introductory learning (Figure 3). During this test, 12 kindergarten and elementary school teachers were invited to observe on the spot and became the

Figure 2. Test prototype "Coding Adventure"
Source: Authors' work

Figure 3. "Coding Adventure" Test screen in the kindergarten
Source: Authors' work

focus group of this study. These teachers all came from kindergartens or primary schools that are offering or planning to offer coding lessons. Some of them have already participated in coding lessons and have teaching experience, and the rest have also participated in lesson preparations.

Considering that the child participants are still young and cannot give accurate evaluation opinions other than whether it is interesting, this study adopted a focus group with teachers as a qualitative research method. Researchers hope to make positive suggestions for developing coding education tools through teachers' teaching observations and combined with their own teaching experience or teaching plans.

The focus group discussion was divided into two groups, with six teachers as participants in each group and two

researchers from our team as moderators. The moderators invited participants to fully express their opinions on the questions in Table 1. After obtaining the consent of the participants, 3.5-hour audio recordings were collected from the focus group discussion. The researchers independently encoded the recordings using the MAXQDA2022 and used the collaboration function to correct for encoding differences. All participants were anonymized and represented by codes in this study. The twelve participants are numbered [T01] to [T12], respectively. Finally, the demographic data of all participants are summarized in Table 2.

Table 2
Demographic characteristics of participants

Characteristic		n	%
Gender	Male	4	33.3
	Female	8	66.7
Age Range	25–34	10	83.3
	35–44	2	16.7
Teaching Years	0–3	5	41.7
	4–6	5	41.7
	6–10	1	8.3
	10+	1	8.3
Teacher Type	Kindergarten Teacher	7	58.3
	Primary School Teacher	5	41.7
Coding Teaching Experience	Yes, I have.	4	33.3
	No, I haven't.	8	66.7

Source: Authors' work

RESULTS

First, the researchers coded the test design objectives from the literature review using MAXQDA software and recorded the codes' frequency to understand the participants' focus (Table 3). The data obtained from the focus group were open-coded by three researchers and negotiated after completion, and the codes that achieved consensus were retained. Finally, these codes were divided into three themes: gamification, unplugged and low-cost, according to the key points of design and questions, making the discussion and conclusion below clearer.

Table 3 displays the ranking of characteristics that participants in the focus group mentioned, from highest to lowest frequency: (1) no electronic devices, (2) role-playing, (3) gamified reward, (4) use of teaching environment, (5) low-cost items, (6) student-oriented, (7) gamified storytelling, and (8) team communication.

The most highlighted feature of the prototype design is that this prototype does not use any electronic equipment so that learners can experience the fun of communicating with teachers and classmates. In this regard, most teachers supported it. Representative comments include the following:

> *"If such a teaching method is maintained, teachers and students will not use electronic devices, which will protect the children's eyesight, and will also reassure the parents of the students"* [T03]

> *"Almost all coding education now relies on computers and pads, which makes students easily distracted, and they often switch to other games secretly, which makes teaching difficult"* [T02]

Table 3
Qualitative analysis statistics

Theme	Code	Frequency	Representative Quote
Gamification	Role-playing	15	Children like to play the role of knights, even little girls, which brings them a sense of justice. [T01]
	Gamified reward	11	Rewarding children with points and badges as the game progresses works well, and they really care about the accolades. [T10]
	Gamified storytelling	8	Children like the story of knights fighting monsters in the game very much. Such stories can quickly generate motivation for children to learn. [T03]
	Team communication	7	Children who cannot pass the game levels will discuss countermeasures with their teammates, which rarely occurs in other courses. [T02]
Unplugged	No electronic devices	18	If such a teaching method is maintained, teachers and students will not use electronic devices, which will protect the children's eyesight and reassure the parents of the students. [T03]
	Use teaching environment	10	Using the classroom or playground directly is a great idea so students can move around during class instead of staring at blackboards and screens all day. [T09]
Low-cost	Low-cost items	9	It is a good idea to use foam floor mats and inflatable toys so that schools and general teaching institutions can afford the investment in classroom equipment and children can use it safely. [T09]
	Student-oriented	8	Such a design can fully consider the feelings of each participating child, allow each of them to play, and save resources. [T11]

Source: Authors' work

> *"It is inevitable for us to use electronic devices in class. However, now all courses and homework need to use electronic devices, which makes parents very worried about children's vision health"* [T11]

Secondly, the feature of allowing students to play a role in the game to increase their sense of participation in the prototype design has also received more attention.

> *"Children like to play the role of a knight, even a little girl; it brings them a sense of justice"* [T01]

> *"The idea of role-playing is nice, so the teacher does not need to spend extra time explaining the game's goal to them; they can understand it by themselves"* [T07]

> *"The children played very seriously, and it could be seen that they were involved. As long as they are interested, the learning effect will be better"* [T12]

Thirdly, gamification rewards have also received much attention, which can effectively motivate student learning motivation.

"Rewarding children with points and badges as the game progresses works well, and they care about the accolades" [T10]

"Students are very interested in rewards and are willing to collect all kinds of small medals given to them by teachers in school" [T04]

In addition, reasonable use of the teaching environment and low-cost items are often mentioned together. These design features allow teachers to organize course teaching quickly.

"Using the classroom or playground directly is a great idea so students can move around during class instead of staring at blackboards and screens all day" [T09]

"It is a good idea to use foam floor mats and inflatable toys so that schools and general teaching institutions can afford the investment in classroom equipment and children can use it safely" [T09]

"We can easily get these simple items from online shopping and then put them in the classroom and use them directly. It is a very good suggestion. I even think students can be encouraged to bring some safe toys from home as game scenes. Then we can play the game ourselves in the corner of the classroom" [T05]

The teacher respondents also recognized the student-oriented concept, and some opinions were expressed as follows:

"The gamification design considers students' cognitive ability and can effectively drive their learning motivation, which is interesting" [T04]

"Modern education cannot require children to avoid contact with games completely, so we should use the power of games to stimulate students' learning enthusiasm. In teaching, we can further consider students' preferences, allow them to increase their understanding of programming, and add them to new game levels, which should be more interesting" [T07]

Finally, gamified storytelling and team communication are often mentioned together. These two features can make students more involved in gamified situations.

"Children like the story of knights fighting monsters in the game very much. Such stories can quickly generate motivation for children to learn" [T03]

"Children who cannot pass the game levels will discuss countermeasures with their teammates, which rarely occurs in other courses" [T06]

"Today's children are familiar with the story of fighting monsters and upgrading in games so that

they will have a good sense of substitution. Forming a team to take risks in the story is necessary, so their communication skills will also be encouraged. It is suggested that more background stories of multiplayer cooperation can be set in the game so children can interact more" [T10]

"I suggest adding more logical dialogues to the game. On the one hand, it can increase the storyline, and on the other hand, it can strengthen the children's dialogue logic" [T12]

The quantitative analysis results show that most participants (10 out of 12) expressed the advantages of gamification, unplugged and low cost in improving the perceived usefulness and ease of use of coding education tools. The researchers also further summarized the evidence given by participants to verify the hypotheses proposed in this study based on the TAM theory (Table 4). The results demonstrate sufficient evidence that the children's coding education tool, under the influence of gamification, is unplugged and low-cost, provides sufficient perceived usefulness and ease of use for educators, and finally affects the actual use of the system.

DISCUSSION

Through focus group discussions, this study gathered feedback from teachers who used a coding education tool specifically designed for children. The qualitative

Table 4
Hypothesis testing result

Hypothesis	Theme	Representative Quote
H1. The children's coding education tool, under the influence of gamification, is unplugged and low-cost, provides sufficient perceived usefulness for educators, and finally affects the actual use of the system.	Gamification	Children like the story of knights fighting monsters in the game very much. Such stories can quickly generate motivation for children to learn. [T03] The gamification design considers students' cognitive ability and can effectively drive their learning motivation, which is interesting. [T04] Rewarding children with points and badges as the game progresses works well, and they really care about the accolades. [T10] The children played very seriously, and it could be seen that they were involved. As long as they are interested, the learning effect will be better. [T12]
	Unplugged	The advantage of being unplugged is that it allows students to focus all their attention on teaching, improving the teaching effect. [T01] If such a teaching method is maintained, teachers and students will not use electronic devices, which will protect the children's eyesight and reassure the parents of the students. [T03]
	Low-cost	Students can make simple game props after class to exercise their hands-on skills. [T08] Such a design can fully consider the feelings of each participating child, allow each of them to play, and save resources. [T11]

Table 4 *(continue)*

Hypothesis	Theme	Representative Quote
H2. The children's coding education tool, under the influence of gamification, is unplugged and low-cost, provides sufficient perceived ease of use for educators, and finally affects the actual use of the system.	Gamification	Students are very interested in rewards and willing to collect all kinds of small medals given to them by teachers in school. [T04] The idea of role-playing is nice, so the teacher does not need to spend extra time explaining the game's goal to them; they can understand it by themselves. [T07] Rewarding children with points and badges as the game progresses works well, and they care about the accolades. [T10]
	Unplugged	Teachers will save trouble if existing teaching resources can be used to simulate game scenarios. [T04] Using the classroom or playground directly is a great idea so students can move around during class instead of staring at blackboards and screens all day. [T09]
	Low-cost	We can easily get these simple items from online shopping and then put them in the classroom and use them directly. It is a very good suggestion. I even think students can be encouraged to bring some safe toys from home as game scenes. Then, we can play the game ourselves in the corner of the classroom. [T05] It is a good idea to use foam floor mats and inflatable toys so that schools and general teaching institutions can afford the investment in classroom equipment and children can use it safely. [T09]

Source: Authors' work

results are diverse in content, discussed in two parts below.

The first part discusses the perceived usefulness and ease of use of the children's coding education tool from the perspective of the theoretical framework based on the TAM theory. The results show that adding gamification, unplugged and low-cost design elements to the children's coding education tool can indeed enhance both perceived usefulness and perceived ease of use, and both perceived usefulness and perceived ease of use for educators finally affect the actual use of the system.

In terms of perceived usefulness, gamified role-playing and rewards improve children's effectiveness in using the education tool; the unplugged setting also protects children's visual health and gains parents' trust; low-cost entity props can also improve children's hands-on abilities. In terms of perceived ease of use, gamification settings reduce the difficulty of explanations for educators, and gamified rewards strengthen children's motivation to participate; unplugged gamification scenarios make it easier for educators to use existing teaching resources; and low-cost and safe teaching props can be easily purchased by educators online.

The second part discusses the effects of these design elements, such as gamification, unplugged and low-cost in this prototype, and educators' views on them. It thoroughly evaluated the future development direction of this kind of educational tool. After this feedback is coded and analyzed, it can still be summarized into three themes for

discussion based on the previously set themes:

First, gamification, as the theme that attracted the most attention from participants, showed four elements in this study: (1) role-playing, (2) gamified reward, (3) gamified storytelling and (4) team communication. Among them, role-playing, gamed storytelling and team communication are highly related. Role-playing has always been important for children to develop enlightenment education (Jasutė, 2020; Lin et al., 2021). Teacher participants generally stated in group discussions that adding gamified adventure stories to education tools can effectively enhance the immersion of child learners and encourage them to bravely play game roles. The test prototype in this study uses simple items and clothing so that students can quickly perform role-playing and integrate into the game characters to have more sense of substitution, which the teachers recognize.

While playing the role, the learners actively communicated as a team after taking on the role of the game story, encouraging each other and discussing countermeasures. This social interaction method differs from the communication model between humans and computers in traditional computer learning. Gamified stories and verbal communication played an important role in testing the prototype. Students expressed full interest in the imagination and communication provided by gamification elements. Çakır et al. (2021) also showed similar results; that is, the imaginative and original elements in the language domain significantly impact the children's problem-solving ability in coding education.

In addition, gamified rewards are widely used in coding educational games (Demir, 2021; Nie et al., 2021). The test prototype further demonstrated to the teacher how gamified rewards such as badges, points, and souvenirs could motivate students. Teachers observed that child participants were motivated by gamified rewards during the learning process to persist in completing learning behaviors. Giving gamified rewards enhances the child participants' interest in learning and gives them a sense of honor. Gamification elements play a diverse role in children's coding education tools, which can enhance the motivation of child participants while improving their imagination and expression abilities.

Second, the test prototype presented an unplugged solution for coding education, which proved to gain support from kindergarten and elementary school teachers. The unplugged program is promoted in elementary coding courses to safeguard students' health and make flexible use of the school's existing resources. According to a survey, 80% of parents support the idea that their children should not use electronic devices during school hours, which is beneficial for their physical and mental health and helps cultivate study habits (Bourjaili-Radi et al., 2020). Teachers in this study expressed similar concerns. Teachers generally believe that exposing children to electronics too early leads to addiction and distracts them from learning. They also

reported parents' resistance to electronic courses for younger children.

In addition, the unplugged design allows teachers to arrange teaching scenes in ordinary classrooms and playgrounds. On the one hand, it can make full use of the teaching environment that teachers and students are familiar with; on the other hand, it can also promote students' motor functions to the fatigue caused by always staring at the projection or screen in class. The above discussion reflects that the unplugged design included in this children's coding education tool can meet the comprehensive needs of students' health, teachers' convenience and school resource allocation. Yang (2018) also emphasizes the importance of unplugged role-playing for computer-enlightenment learning.

Third, using low-cost and available materials instead of expensive electronic products to stimulate children's interest in coding education has proved an effective solution (Brackmann et al., 2019). Moreover, it fits well with the other two design features of the test prototype: "use of low-cost items" and "use of teaching environment adapted to local conditions." Using the school's existing resources and encouraging students to create their game items and scenes can enhance students' hands-on abilities and reduce the cost of popularizing lessons. In addition, the low-cost design advocated by this coding education tool does not simply use cheap materials. However, it selects items suitable for students from a student-oriented perspective to cater to their preferences and better promote coding education.

In general, unplugged and low-cost gamification can well detect the influence of perceived usefulness and perceived ease of use on educators' actual use of children's coding education tools under the framework of TAM theory. Of the three design features focused on in this study, gamification received the most significant endorsement from educators. Other related studies have also given similar conclusions, that is, gamification has a significant role in promoting the perceived usefulness and ease of use of the system (Dhahak & Huseynov, 2020; Panagiotarou et al., 2020; Zainoddin et al., 2022). Unplugged physical teaching is a compromise function developed for young students in this research. However, educators have generally recognized it, and it has indeed been proven to be highly practical for the promotion of early programming teaching (Babić & Čičin-Šain, 2023). Low cost is closely related to the ease of use of the system in most cases because it can improve users' acceptance of the system, which is also confirmed in this study (Bettayeb et al., 2020).

This study's test prototype enhances student learning motivation, encourages problem-solving to seek help, fosters creativity and critical thinking, and promotes active interaction with students. These design objectives are generated around student-centered ideas (Kim, 2019).

CONCLUSION

This study tested the children's coding education tool with gamification, unplugged and low-cost characteristics under the

framework of TAM theory. The audience of educators recognized the perceived usefulness and ease of use, which could make them accept the teaching method of this educational tool.

An unplugged tool, "Coding Adventure," was designed for children's introductory coding education to verify this viewpoint. The preliminary design ideas and operation methods were shown to the relevant teachers through prototype testing. The researchers learned about the teachers' feedback on the test prototype through the focus group discussion. It further demonstrated the validity of the design idea's insistence on not using electronic devices, adding gamification elements, and using low-cost items combined with the school teaching environment in the design ideas.

Implication for Practice

This study has contributed to the popularization of coding education for younger children. Curriculum solutions combining gamification and unplugged and low-cost design elements can better train children's computational thinking in kindergarten or lower-grade primary school curriculum systems, laying a solid foundation for further learning computer programming. In addition, this type of coding education tool can be used to integrate the cultivation of computational thinking into children's extracurricular games or recess sports, giving teachers and schools more choices in teaching planning. These design objectives adhered to a student-centered approach and were supported by the teachers.

In addition, gamified role-playing, rewards, and storytelling are identified as positive and effective design elements for developing the coding education tool. Gamification elements promote children's active engagement in coding courses and cultivate their teamwork and independent problem-solving abilities. Gamification elements also play positive roles in unplugged and low-cost teaching scenarios, providing a meaningful reference for children's coding education tool developers.

Limitations and Recommendations for Future Research

This study only used focus groups as a qualitative research method, so no other methods were used to collect data for triangulation. The participants in the focus group have similar professional backgrounds and come from educational institutions in a small area, which results in a lack of sufficient representativeness of the results obtained in this study. Moreover, the object of this study is only educators, not students, which leads to an incomplete viewpoint.

Future research directions can be applied to quantitative research to further understand students' feedback and gather design suggestions from a wider range of educators. The researchers plan to fully improve the teaching system to maximize the benefits of gamification mechanisms. The researchers will add more teamwork and communication interaction based on the feedback and suggestions obtained from this test.

ACKNOWLEDGMENTS

This work is funded by Jiangsu Provincial Educational Science Planning Project Key Project (2022), issued by Jiangsu Provincial Education Science Planning Leading Group and Communication University of China, Nanjing. Project title: Innovative Research on Children's Logic Teaching Practice in the Context of Gamification (B/2022/04/42).

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