



BEYOND THE TOUCHSCREEN: PLAYER EXPERIENCE IN A TANGIBLE PROGRAMMING GAME FOR CHILDREN

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ABSTRACT

Aim/Purpose	This study aims to evaluate player experience among children aged 6–8 years in a tangible programming game across the miniPXi dimensions of functional, psychosocial, and enjoyment, and to explore differences in these dimensions by children's tablet use frequency, categorized as often, rarely, or very rarely.
Background	Understanding the player experience is important because the quality of interaction may shape children's immediate engagement and perceived accessibility during early programming activities. While prior research on Tangible User Interface (TUI)-based programming games for children has largely focused on learning outcomes and performance, relatively little empirical work has examined how children experience these games from a player-experience perspective. This gap highlights the need for empirical evaluation of player experience to better inform the design of engaging and inclusive programming games for children.

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Methodology	This study employed a playtesting-based empirical evaluation with 78 children aged 6–8 years. Participants interacted with a tangible programming game using a physical game controller. Player experience was measured using the Mini Player Experience Inventory (miniPXI), a psychometric instrument previously validated in game research and adapted in this study through teacher-supported administration for children aged 6–8 years. Descriptive statistics and nonparametric group comparisons were used to analyze overall player experience and differences across tablet-use frequency groups.
Contribution	This study provides empirical evidence on how children experience a tangible programming game using a player experience instrument previously validated in game research. It extends existing research on tangible programming by foregrounding player experience as a multidimensional evaluative lens and by offering preliminary insights into accessibility-related design considerations.
Findings	The results indicate that the tangible programming game supported generally positive player experiences across functional, psychosocial, and enjoyment dimensions. Strong responses were observed for audiovisual appeal, progress feedback, curiosity, immersion, and enjoyment. Notably, children with less frequent tablet use reported high levels of enjoyment, suggesting that tangible interaction may provide a more accessible and engaging entry point into early programming activities for children with limited prior digital exposure, although this observation requires further investigation.
Recommendations for Practitioners	Designers and educators may consider tangible programming games as a promising approach for supporting engagement among children with varying levels of digital familiarity. Clear visual feedback and intuitive physical interaction can sustain engagement, while additional scaffolding may be needed to improve ease of control and the communication of educational meaning.
Recommendations for Researchers	Researchers are encouraged to incorporate validated player experience instruments when evaluating tangible programming games for children. Player experience measures can complement learning outcomes by providing insight into usability, engagement, and inclusivity in early programming contexts.
Impact on Society	By documenting positive immediate player experiences among children aged 6–8 years, this study suggests that tangible programming games may offer promising entry points into early programming activities, particularly for learners with limited prior digital exposure.
Future Research	Future research may examine the relationship between player experience and learning outcomes, compare tangible programming games with graphical programming games, test such systems in more diverse educational settings, and further validate player experience instruments such as miniPXI for use with very young learners.
Keywords	tangible programming game, player experience, tangible user interface (TUI), early programming education, miniPXI

INTRODUCTION

Educational programming games are increasingly used to introduce computational thinking in early elementary education (Giannakoulas & Xinogalos, 2024; Zhan et al., 2022). In learning-through-play environments, children’s gameplay experience is particularly important because the quality of interaction influences engagement, motivation, and willingness to continue participating in programming

activities (Nadeem et al., 2023). Research in educational technology further suggests that educational games are more effective when they support positive interaction experiences in addition to instructional goals (L. Sun et al., 2023).

Despite continued development of educational programming games, most systems still rely on conventional graphical user interfaces, particularly touchscreen-based drag-and-drop interaction (Lindberg et al., 2018; Miljanovic & Bradbury, 2018). For children, purely touchscreen-based interaction may not always align with preferences for physical and multisensory activities (Baykal et al., 2018). Tangible User Interfaces (TUIs) address this limitation by enabling children to manipulate physical objects that control digital outcomes, thereby supporting more embodied and intuitive forms of interaction (Rodić & Granić, 2022). Systematic reviews of early learning technologies also indicate growing design and research interest in tangible interaction approaches, suggesting that tangible-based programming tools are becoming increasingly relevant in educational practice (Macrides et al., 2022).

Existing research on tangible-based programming systems has primarily examined educational outcomes such as learning performance and related instructional indicators (Lee et al., 2024; Molina et al., 2025). Other studies have focused on motivation, engagement, learning curves, and collaborative learning in tangible programming environments (Almjally et al., 2020; Marfisi-Schottman et al., 2019; Wong-Aitken et al., 2023). While these studies demonstrate the pedagogical potential of tangible-based programming tools, they provide limited insight into how children experience such systems from a player experience perspective during gameplay. This gap is critical because children may complete programming tasks while still experiencing difficulties with control, feedback, or enjoyment, which can undermine sustained engagement and classroom adoption (Johnson et al., 2018).

The need for a systematic evaluation of player experience is also timely. A systematic review of assessment measures in game-based learning reported that learning outcomes are evaluated far more frequently than engagement and usability, and that many studies rely on instruments without strong psychometric validation (Gris & Bengtson, 2021). Strengthening player experience evaluation can therefore improve the methodological rigor of educational game research and provide more actionable guidance for designing engaging and inclusive programming games for children.

To address this gap, the present study evaluates players' experiences with a tangible programming game for children using the Mini Player Experience Inventory (miniPXI). The miniPXI is a validated psychometric instrument designed to measure player experience across functional, psychosocial, and enjoyment dimensions (Haider et al., 2022; Harteveld et al., 2020). Its concise structure makes it suitable for playtesting studies involving children, provided that the evaluation procedure is developmentally appropriate. Child-computer interaction research further emphasizes the importance of child-centered evaluation approaches that enable children to reliably express their experiences when instruments and procedures are adapted to their cognitive and communicative abilities (Druin, 1999; Read, 2008; Read & MacFarlane, 2006). Based on these considerations, this study investigates the following research questions:

- RQ1:** How do children evaluate their player experience in a tangible programming game across functional, psychosocial, and enjoyment dimensions?
- RQ2:** Which player experience dimensions represent strengths, and which indicate design challenges in tangible programming interaction for children?
- RQ3:** How does player experience differ across children with varying levels of tablet use frequency?

Having established the research gap and research questions related to player experience in tangible programming games, the following section reviews prior work on educational programming games, tangible user interfaces, and player experience research.

LITERATURE REVIEW

EDUCATIONAL PROGRAMMING GAMES FOR CHILDREN

Educational programming games have been widely adopted to introduce computational thinking concepts to children at an early age. These games typically aim to provide accessible learning experiences by embedding algorithmic thinking within playful activities that reduce anxiety and cognitive barriers associated with traditional programming instruction (Giannakoulas & Xinogalos, 2024). Research has shown that game-based approaches can support children’s motivation and engagement when learning abstract computational concepts by presenting these concepts in interactive, goal-oriented formats (Zhan et al., 2022).

Block-based and game-based programming environments have been particularly influential in early programming education, as they enable children to experiment with logic and sequencing without requiring syntactic precision (Kanika et al., 2020). Empirical studies indicate that such environments can foster initial interest in programming and support conceptual understanding when tasks are appropriately scaffolded (Fokides, 2017). However, prior research has also highlighted that successful learning outcomes do not depend solely on curriculum design or task structure but are influenced by how children interact with and experience the learning system during gameplay (Nadeem et al., 2023).

Despite their educational benefits, many educational programming games are evaluated primarily in terms of learning performance or attitudinal outcomes, while the quality of player experience itself is often treated as a secondary concern. This limitation suggests the need to consider children not only as learners but also as players whose interaction experiences may shape engagement, persistence, and accessibility in practice.

TANGIBLE USER INTERFACES IN LEARNING

TUIs have emerged as an alternative interaction paradigm that enables users to interact with digital systems through physical objects (Ishii & Ullmer, 1997; Krestanova et al., 2021). In learning contexts, TUIs are often described as supporting embodied interaction, allowing children to use physical manipulation as part of sense-making and problem-solving (Baykal et al., 2018). Prior research has suggested that tangible interaction may be particularly suitable for young children, whose cognitive development is closely tied to sensorimotor activity and physical exploration (Rodić & Granić, 2022).

In programming education, TUIs have been used to support learning outcomes such as conceptual understanding, collaboration, and engagement. Empirical studies have reported positive effects of tangible programming systems on learning performance and collaborative problem solving (Lee et al., 2024; Wang et al., 2024). Systematic reviews further indicate that tangible programming environments can facilitate exploration and reduce abstraction barriers compared to purely touchscreen-based interfaces (Macrides et al., 2022; Molina et al., 2025).

However, most evaluations of tangible programming systems have focused on educational outcomes rather than on the quality of children’s gameplay experience. While engagement or motivation is sometimes measured, it is often treated as a single construct and not examined as a multidimensional player experience. As a result, existing studies provide limited insight into how children perceive control, feedback, challenge, or enjoyment during tangible programming gameplay.

PLAYER EXPERIENCE IN EDUCATIONAL GAMES

Player experience is a multidimensional construct that encompasses how players perceive and emotionally respond to gameplay, including functional, psychosocial, and affective dimensions of interaction. In game research, player experience has been recognized as an important indicator of design quality, usability, and engagement (Johnson et al., 2018). Rather than focusing solely on task completion or performance, player experience evaluation seeks to capture how interaction is experienced from the player’s perspective.

In educational games, positive player experience has been associated with higher engagement and sustained participation, which are critical for learning environments that rely on repeated interaction (Pellas, 2024). Constructs such as curiosity, immersion, autonomy, and enjoyment have been identified as key factors that influence whether players remain engaged with educational games beyond initial exposure (Chandra et al., 2025). These dimensions are particularly relevant when designing games for children, who may be more sensitive to frustration, usability issues, and unclear feedback.

Despite its importance, player experience remains underexamined in the context of educational programming games, especially those using tangible interaction. Many studies focus on confirming the effectiveness of learning without examining how children experience gameplay as players. This gap highlights the need for player experience-focused evaluation frameworks that can inform both game design and educational practice.

MEASURING PLAYER EXPERIENCE WITH CHILDREN

Measuring player experience with children presents distinct methodological challenges related to cognitive development, communication skills, and response reliability. Child-computer interaction research has emphasized the importance of child-centered evaluation approaches that enable children to express their experiences meaningfully and reliably (Druin, 1999). Evaluation instruments must therefore be developmentally appropriate, concise, and supported by facilitation strategies when used with young participants.

Several instruments have been developed to measure children's experiences with interactive systems, including tools specifically designed for child-centered evaluation, such as the Fun Toolkit (Read, 2008; Read & MacFarlane, 2006). These studies demonstrate that children are capable of reflecting on their experiences when questions are clearly worded, and procedures are adapted to their abilities. However, many child-centered instruments focus on general usability or enjoyment and may not capture the broader multidimensional structure of player experience relevant to game design.

The miniPXI offers a concise psychometric instrument for measuring player experience across functional, psychosocial, and enjoyment dimensions (Haider et al., 2022; Harteveld et al., 2020). Originally developed and validated in game research, the miniPXI provides a structured framework that aligns well with player experience theory. While its application with young children requires careful implementation, prior research in child-centered evaluation has shown that validated evaluation instruments can be adapted for use with children when supported by developmentally appropriate procedures (Druin, 1999; Read & MacFarlane, 2006).

Taken together, the existing literature indicates a need for empirically grounded approaches to evaluate player experience in educational programming games for children, using validated instruments. Addressing this gap can strengthen both methodological rigor and practical insights into how tangible programming games are experienced by young players. Based on the identified gaps in existing research, the next section describes the methodology used to evaluate children's player experience in a tangible programming game.

METHODOLOGY

PARTICIPANTS AND SAMPLING STRATEGY

This study involved 78 children (37 females, 41 males) aged 6–8 years ($M = 7.14$, $SD = 0.45$) who were first and second-grade elementary school students in Indonesia. Participants were recruited using convenience sampling, based on accessibility and school participation during scheduled playtesting sessions. Participation was voluntary, and written consent was obtained from parents, with teachers assisting as facilitators during the playtesting process.

The sample size was considered sufficient for the study's primary aim, namely, the evaluation of player experience in a tangible programming game using a validated psychometric instrument. From

a usability and playtesting perspective, studies have shown that meaningful insights into user experience can be obtained with moderate sample sizes, with diminishing analytical returns as the number of participants increases (Nielsen & Landauer, 1993). The relatively large sample ($N = 78$) also enabled exploratory comparisons across participant subgroups, particularly based on differences in prior tablet use frequency.

To explore potential differences related to prior digital exposure, participants were classified into three groups based on tablet use frequency: Often (almost every day), Rarely (two to three times per week), and Very Rarely (seldom). This classification was based on children's self-reports collected before playtesting, with teachers assisting to ensure that participants understood the question. As this measure relies on self-report, it is treated as an approximate indicator of digital familiarity rather than a precise behavioral measure.

GAME APPLICATION

The game used in this study was Code the Cat (as illustrated in Figure 1), a tile-based educational programming game developed specifically for research purposes. The game was designed by adopting principles commonly applied in educational programming games (Hsu et al., 2018; Tikva & Tambouris, 2021), such as ScratchJr (Flannery et al., 2013) and Code.org (Kalelioğlu, 2015). The TUI approach was implemented using a game controller consisting of tangible boxes that function as command blocks. As a web-based application, the game can be played on a laptop or tablet.

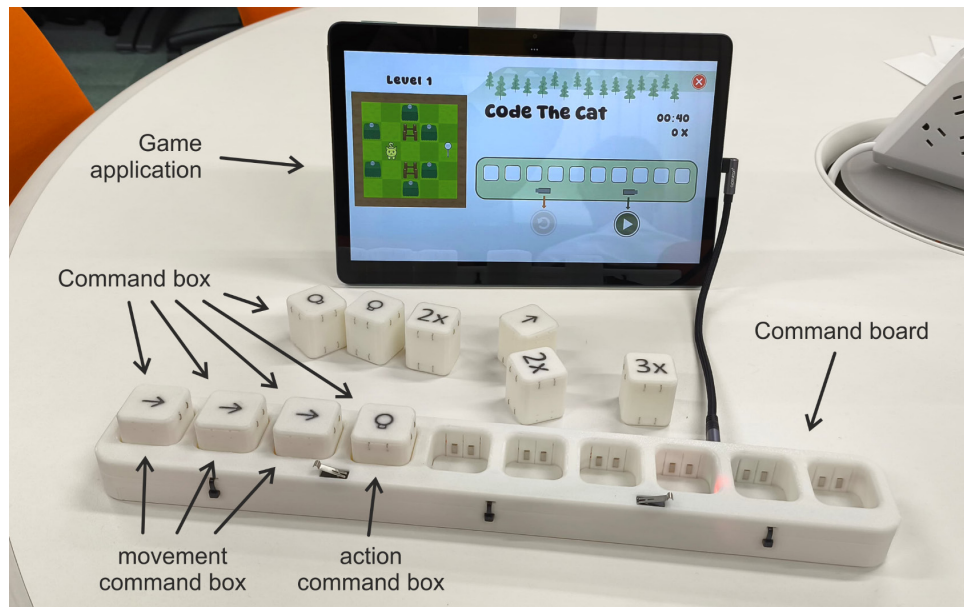


Figure 1. Code the Cat game system (game application and game controller)

An illustration of the game controller mechanism is shown in Figure 2. The game controller was developed using an Arduino Pro Micro, which is responsible for identifying each command block placed on the command board. Identification is performed by reading the resistance value associated with each command block. To support this mechanism, a resistor with a unique resistance value is embedded on each side of the command block. To address the limitation of the Arduino Pro Micro in identifying all command blocks within a short time frame, particularly due to the limited number of available analog input pins, a multiplexer was employed. The identification process runs continuously, allowing any changes to the arrangement of the command blocks to be detected immediately and reflected in the game application.

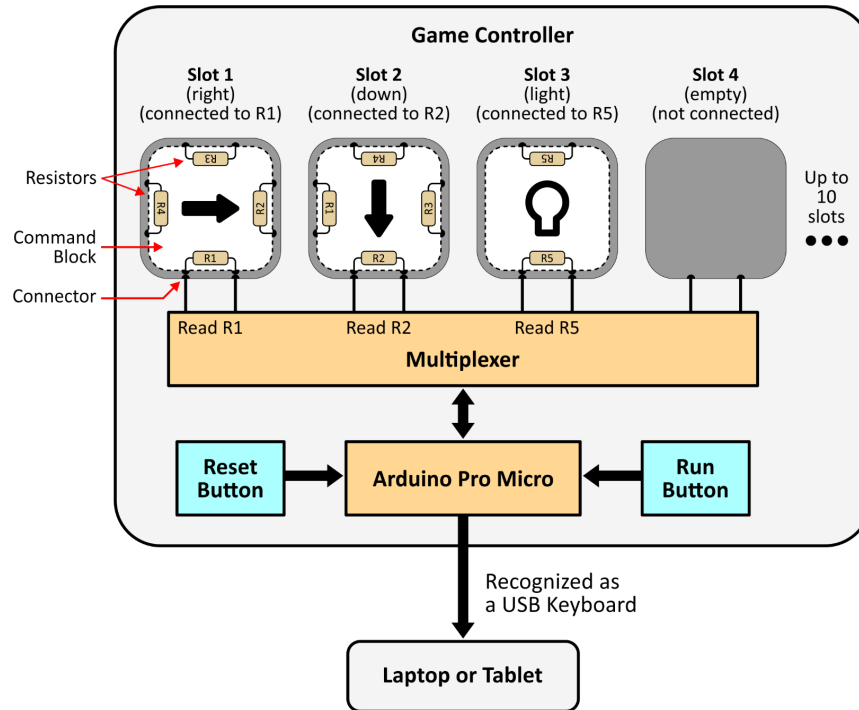


Figure 2. The working mechanism of the game controller

Once all resistance values from each command block slot have been collected, the Arduino Pro Micro processes these values into a string-based code, which is then transmitted to the device running the game application. This mechanism is supported by the Arduino Pro Micro's ability to be recognized as a keyboard input device by laptops or tablets. With this approach, the game controller is treated as a general keyboard and can be used conveniently via a plug-and-play model. Upon receiving the string-based code, the game application parses the input and updates the internal game state, including the command sequence, character actions, and the game layout.

Figure 3 shows the layout of the gameplay page. Inspired by the Light-Bot game (Gouws et al., 2013), the main mission of the game is to control a character to light one or more lamps located on the game map. Players must arrange command blocks in the correct order on the command board and then execute them by pressing the run button. If errors occur, players can revise the arrangement of command blocks and re-run the character.

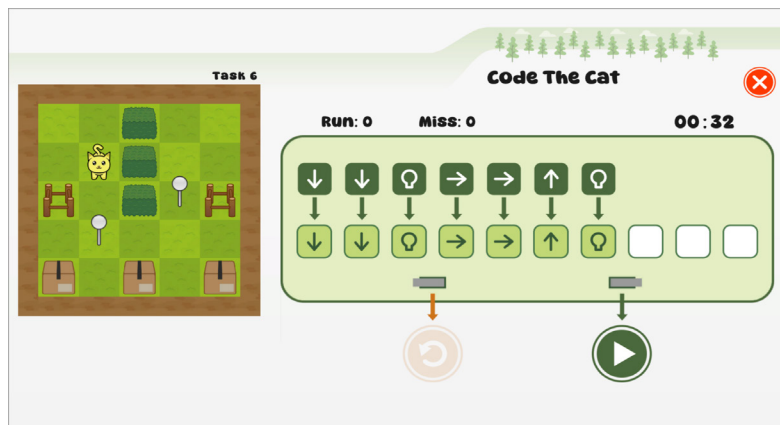


Figure 3. Layout of the main gameplay page in Code the Cat

The gameplay page consists of two main sections: the game map on the left, which represents the challenge, and the visual command board on the right, which displays the arranged commands. The visual command board is automatically updated when players add or remove command blocks on the game controller. When the run button is pressed, the main character, represented by the yellow cat, moves according to the arranged commands. Five commands were available: move up (U), right (R), down (D), left (L), and turn on the lamp (T).

EXPERIMENTAL TASK

Table 1 presents the details of the experimental tasks. The study employed 10 experimental tasks, each with increasing difficulty as indicated by the number of commands required. Since the primary objective was to evaluate player experience rather than task performance, participants were not required to complete all tasks. They were free to finish all tasks or stop at a certain task, depending on their comfort level.

Table 1. Task levels based on the number of commands

Task	Number of commands	Command pattern
task 1	5	L D D R T
task 2	5	R U R U T
task 3	6	R D D L L T
task 4	6	R D T R D T
task 5	7	L L D D R R T
task 6	7	D D T R R U T
task 7	8	L U U T R R D T
task 8	8	L U L T U U R T
task 9	9	L D L D T D R D T
task 10	10	R R U U L T L L D T

Game maps were developed based on predetermined command patterns. Examples of game maps are provided in Figure 4 to illustrate task design. Character movement was restricted by obstacles such as cardboard boxes, wooden fences, or bushes. Some obstacles were strategically placed to prevent alternative solutions, ensuring that each mission could only be completed using the designated command pattern.

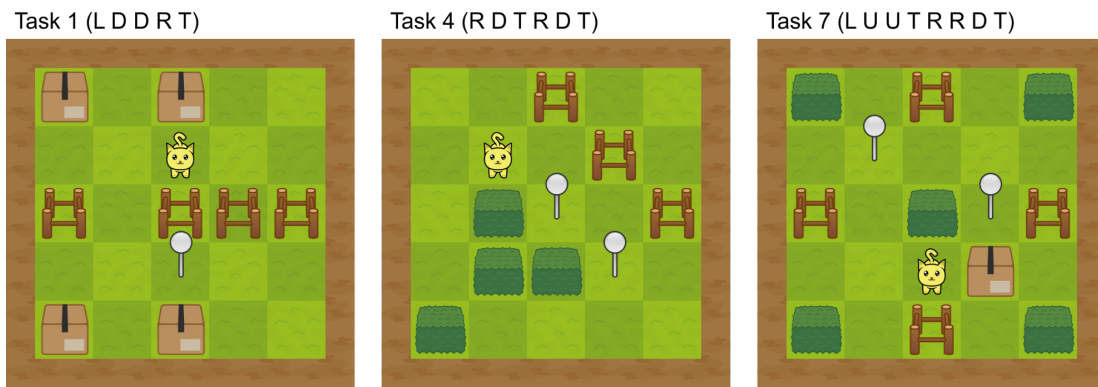


Figure 4. Game maps for task 1, task 4, and task 7

MEASUREMENT

The evaluation specifically aimed to assess the quality of player experience resulting from the implementation of TUI in the game. Given the integration of physical and digital interactions, player experience was considered a relevant indicator for evaluating the success of the TUI approach in educational games (Akyaman & Alppay, 2024).

The evaluation scale used was the miniPXI, a shortened version of the Player Experience Inventory (PXI) developed by Vanden Abeele et al. (2016, 2020). Although it contains fewer items than PXI, previous studies have demonstrated the reliability of miniPXI in measuring player experience (Haider et al., 2023, 2024). The instrument was selected because it provides a concise yet comprehensive measurement of player experience across functional, psychosocial, and enjoyment dimensions. The instrument consists of 11 constructs grouped into three dimensions: functional (audiovisual appeal, challenge, ease of control, clarity of goal, progress feedback), psychosocial (autonomy, curiosity, immersion, mastery, meaning), and enjoyment.

It should be noted that the miniPXI was not originally developed specifically for very young children. The use of the miniPXI in this study is supported by adaptation strategies and should therefore be interpreted with appropriate caution. The questionnaire items used in this study are presented in Table 2.

Table 2. MiniPXI questionnaire items used in the evaluation process

Dimension	Construct	Item
Functional	Audiovisual Appeal	I liked the visual design and overall feel of the Code the Cat game.
Functional	Challenge	The Code the Cat game was not too easy and not too hard to play.
Functional	Ease of Control	It was easy for me to understand how to perform actions in the Code the Cat game.
Functional	Clarity of Goal	The goals of the Code the Cat game were clear to me.
Functional	Progress Feedback	Code the Cat game provided clear feedback on my progress toward the goals.
Psychosocial	Autonomy	I felt free to play the Code the Cat game in my own way.
Psychosocial	Curiosity	I wanted to explore how the Code the Cat game evolved during gameplay.
Psychosocial	Immersion	I was fully focused while playing the Code the Cat game.
Psychosocial	Mastery	I felt competent at playing the Code the Cat game.
Psychosocial	Meaning	Playing the Code the Cat game was meaningful to me.
Enjoyment	Enjoyment	I had an enjoyable time playing the Code the Cat game.

All questionnaire items were translated into Indonesian to ensure comprehension by participants. The translated version was reviewed by teachers to confirm age-appropriate wording and conceptual clarity. To further support understanding, questionnaire items were presented with teacher assistance. During questionnaire completion, teachers clarified the meaning of each statement when necessary but did not suggest or influence responses. This form of non-directive support aligns with child-centered evaluation practices and is considered appropriate when collecting self-report data from children (Druin, 1999; Read & MacFarlane, 2006).

Responses were collected using a 7-point Smiley Face Likert scale (Hall et al., 2016), ranging from “Strongly Disagree” to “Strongly Agree”, with the questionnaire items randomized to minimize response bias, following the methodological recommendations of Vanden Abeele et al. (2020). An example of the Smiley Face Likert scale used in this study is shown in Figure 5. The use of visual response formats (e.g., Smiley Face Likert scale) has been recommended for studies involving young children, as visual cues can reduce cognitive load and support comprehension of ordinal response options (Borgers et al., 2004; Mellor & Moore, 2014).

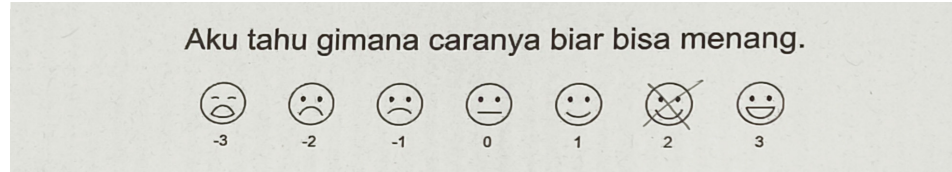


Figure 5. Example of a questionnaire item with the Smiley Face Likert scale

PROCEDURE

The playtesting process consisted of three main phases: Introduction, Playing, and Evaluation, as illustrated in Figure 6. The Introduction phase was used to explain the objectives and procedures of the playtesting session and to familiarize participants with the game. As part of the Introduction phase, participants completed a structured warm-up activity before the main gameplay. The warm-up involved playing a single example task that required arranging six commands with the game controller. This task was conducted with step-by-step guidance and assistance from instructors or teachers. The purpose of the warm-up session was to familiarize participants with the basic game mechanics, verify their ability to manipulate the game controller, and establish comfort with physical interaction before the experimental tasks.

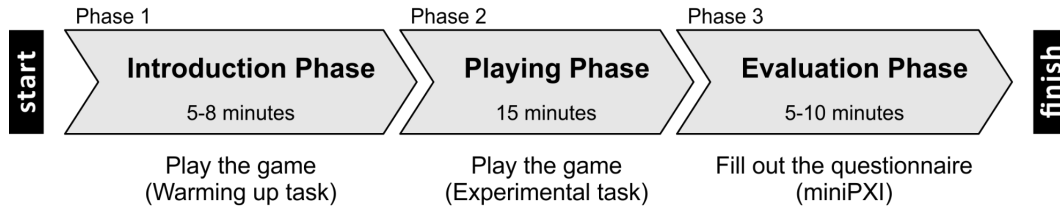


Figure 6. Playtesting procedure

The second phase was Playing, where participants were asked to complete up to 10 experimental tasks within a maximum of 15 minutes, a duration considered appropriate for children when interacting with tablet-based applications (Liu et al., 2021). This duration was considered sufficient for participants to complete multiple gameplay tasks while maintaining attention and avoiding fatigue. They were free to stop at any task or continue until all tasks were completed.

The final phase was Evaluation, during which participants completed the miniPXI questionnaire based on their gameplay experience. Teachers were present to support the process and ensure that participants understood the questionnaire statements, while maintaining minimal intervention to reduce bias. This phase was conducted flexibly, allowing participants who had completed the Playing phase to proceed directly to the Evaluation phase.

The playtesting activities were concluded once the participants had completed the Evaluation phase. The overall playtesting process is illustrated in Figure 7. Due to the limited number of devices, playtesting was divided into eight batches. Each batch involved 8 to 10 participants and lasted for approximately 25 to 30 minutes. Teachers acted as facilitators, particularly during the Playing and Evaluation phases. To reduce bias, facilitation was conducted with minimal intervention.



Figure 7. Playtesting session setup

DATA ANALYSIS

Data analysis focused on descriptive statistics and group comparisons. Means and standard deviations were calculated for each miniPXI construct to summarize overall player experience. To examine differences across tablet use frequency groups, the Kruskal-Wallis test was applied, as miniPXI responses are ordinal in nature and may not meet parametric assumptions (Jamieson, 2004). The use of rank-based tests is consistent with established methodological recommendations for ordinal survey data (Dunn, 1964). All statistical analyses were conducted in Python, using libraries for nonparametric analysis.

Using the described playtesting procedure, measurement instrument, and analytical approach, the following section presents the results of the player experience evaluation.

RESULTS

As the miniPXI responses were collected using Likert-type ratings from children aged 6–8 years, the results are first summarized using descriptive statistics to provide an overall profile of player experience across constructs. Descriptive statistics provide an appropriate initial summary of central tendency and variability across player experience dimensions, but they are insufficient for determining whether observed subgroup differences are statistically meaningful. Because Likert-type responses are ordinal, inferential comparisons should be interpreted cautiously and preferably supported by nonparametric methods (Jamieson, 2004).

The results of the player experience evaluation, based on miniPXI responses from 78 participants, are summarized in Table 3. The instrument consisted of 11 constructs grouped into three dimensions: functional, psychosocial, and enjoyment. The miniPXI scale ranges from -3 (strongly disagree) to $+3$ (strongly agree), where values above 0 indicate positive experiences and values approaching $+3$ represent highly positive experiences (Vanden Abeele et al., 2020). Based on this interpretation, all constructs fell within the positive range, indicating that participants generally reported favorable gameplay experiences. To provide an overview of player experience across constructs, the mean miniPXI scores are visualized in Figure 8.

Table 3. Player experience evaluation using the miniPXI

Dimension	Construct	Mean	SD
Functional	Audiovisual Appeal	2.73	0.66
Functional	Challenge	2.35	1.28
Functional	Ease of Control	2.17	1.41
Functional	Clarity of Goal	2.27	1.35
Functional	Progress Feedback	2.63	0.84

Dimension	Construct	Mean	SD
Psychosocial	Autonomy	2.26	1.32
Psychosocial	Curiosity	2.55	1.15
Psychosocial	Immersion	2.47	1.11
Psychosocial	Mastery	2.28	1.29
Psychosocial	Meaning	2.21	1.53
Enjoyment	Enjoyment	2.58	1.03

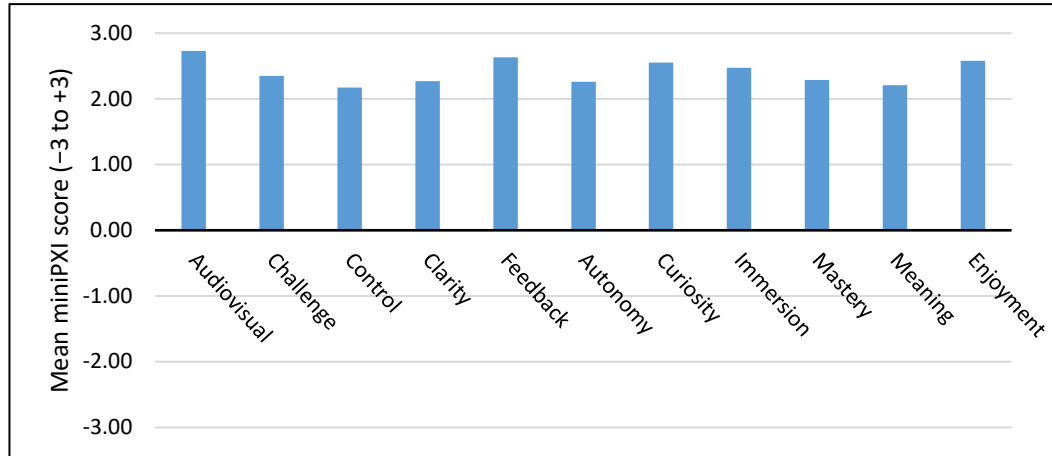


Figure 8. Mean miniPXI scores across all constructs

FUNCTIONAL DIMENSION

Within the functional dimension, audiovisual appeal obtained the highest score ($M = 2.73$, $SD = 0.66$), indicating that participants consistently perceived the game's visual presentation as attractive and engaging. Progress feedback also achieved a high score ($M = 2.63$, $SD = 0.84$), suggesting that the system effectively communicated task progress and outcomes during gameplay. The constructs challenge ($M = 2.35$, $SD = 1.28$) and clarity of goal ($M = 2.27$, $SD = 1.35$) also received favorable evaluations, indicating that participants generally understood the gameplay objectives and perceived the tasks as appropriately challenging. However, the relatively high standard deviations suggest variability in how participants experienced task difficulty. Among the functional constructs, ease of control recorded the lowest score ($M = 2.17$, $SD = 1.41$) and the highest variability. Although the game controller was generally perceived positively, some participants required time to adapt to the interaction.

Taken together, high ratings in audiovisual appeal and progress feedback suggest that children could quickly perceive what was happening on the screen and receive confirmation of their progress, both of which are critical for maintaining engagement in short play sessions. In contrast, the comparatively lower ease of control score indicates that tangible interaction can introduce an additional learning curve for some children, highlighting the need for game controller designs that better match children's motor skills and interaction habits.

PSYCHOSOCIAL DIMENSION

Within the psychosocial dimension, curiosity ($M = 2.55$, $SD = 1.15$) and immersion ($M = 2.47$, $SD = 1.11$) obtained high scores, indicating that participants demonstrated strong exploratory behavior and sustained attention during gameplay. The constructs autonomy ($M = 2.26$, $SD = 1.32$) and mastery ($M = 2.28$, $SD = 1.29$) also received positive evaluations, suggesting that many participants experienced a sense of freedom in decision-making and perceived competence while interacting with the

game. Meaning recorded the lowest score within this dimension ($M = 2.21$, $SD = 1.53$), indicating that although some participants were able to associate gameplay with programming concepts, the perceived educational meaning varied across participants.

The prominence of curiosity and immersion suggests that the tangible interaction and task structure may encourage exploratory engagement and focused attention during gameplay. However, the relatively lower meaning score suggests that some children experienced the activity primarily as play rather than explicitly connecting it to programming concepts, implying a need for design cues or reflection prompts that make learning meaning more visible without increasing cognitive burden.

ENJOYMENT DIMENSION

The enjoyment construct showed a high positive score ($M = 2.58$, $SD = 1.03$), indicating that participants generally found the gameplay enjoyable. The observed variability suggests that enjoyment levels differed across participants, potentially reflecting differences in how smoothly children adapted to the game controller and interpreted feedback. Beyond overall positivity, the high enjoyment score suggests that tangible interaction may offer a potentially engaging and accessible entry point for children. This finding supports the use of tangible interfaces to promote engaging experiences, while also highlighting the importance of inclusive interaction design and adequate guidance to accommodate individual differences among players.

PLAYER EXPERIENCE BY TABLET USE FREQUENCY

Table 4 presents player experience scores across groups categorized by tablet use frequency. Overall, the Often group reported higher mean scores on most constructs than the other groups. The most prominent constructs in this group were audiovisual appeal ($M = 2.97$) and challenge ($M = 2.83$). In the functional dimension, progress feedback recorded the lowest score in the Very Rarely group ($M = 1.89$), while the Rarely group ($M = 2.69$) and Often group ($M = 2.77$) reported higher values. These comparisons provide descriptive insights into potential differences in player experience across groups with varying levels of tablet familiarity.

Table 4. Player experience evaluation across tablet use frequency groups

Dimension	Construct	Very rarely (N = 9)		Rarely (N = 39)		Often (N = 30)	
		Mean	SD	Mean	SD	Mean	SD
Functional	Audiovisual Appeal	2.78	0.67	2.54	0.82	2.97	0.18
Functional	Challenge	2.11	1.83	2.03	1.46	2.83	0.46
Functional	Ease of Control	2.33	1.66	1.97	1.50	2.37	1.22
Functional	Clarity of Goal	2.33	1.12	2.13	1.51	2.43	1.22
Functional	Progress Feedback	1.89	1.36	2.69	0.73	2.77	0.68
Psychosocial	Autonomy	2.67	0.71	1.92	1.46	2.57	1.19
Psychosocial	Curiosity	2.11	1.83	2.46	1.17	2.80	0.81
Psychosocial	Immersion	2.78	0.44	2.15	1.35	2.80	0.76
Psychosocial	Mastery	2.44	0.88	1.90	1.48	2.73	0.94
Psychosocial	Meaning	2.33	1.32	1.77	1.77	2.73	1.05
Enjoyment	Enjoyment	2.89	0.33	2.33	1.24	2.80	0.76

Within the psychosocial dimension, the Often group reported high scores for curiosity ($M = 2.80$), immersion ($M = 2.80$), mastery ($M = 2.73$), and meaning ($M = 2.73$). Interestingly, the Very Rarely group reported the highest score for autonomy ($M = 2.67$). For enjoyment, all groups reported positive scores. The Very Rarely group recorded the highest score ($M = 2.89$, $SD = 0.33$), followed by

the Often group ($M = 2.80$, $SD = 0.76$) and the Rarely group ($M = 2.33$, $SD = 1.24$). Figure 9 illustrates the mean miniPXI scores across all constructs for each tablet use frequency group, providing an overview of group-level patterns in player experience.

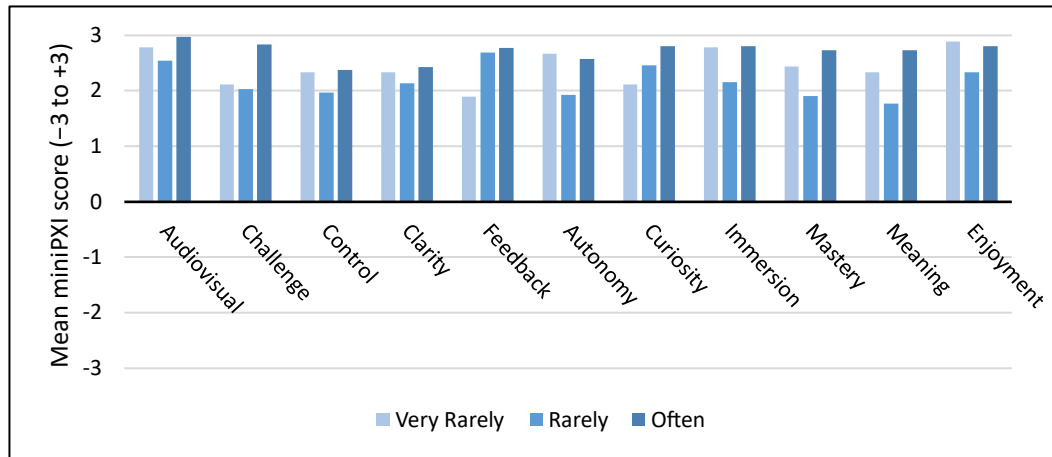


Figure 9. Mean miniPXI scores by tablet use frequency group

To examine group differences across tablet use frequency groups, nonparametric Kruskal-Wallis tests were conducted across miniPXI constructs, given the ordinal nature of Likert-type ratings (Jamieson, 2004). The results revealed a mixed pattern of statistically significant and non-significant effects. Statistically significant differences were found for meaning ($H = 10.39$, $p = 0.006$), immersion ($H = 8.65$, $p = 0.013$), mastery ($H = 8.32$, $p = 0.016$), audiovisual appeal ($H = 7.78$, $p = 0.021$), autonomy ($H = 7.03$, $p = 0.030$), and challenge ($H = 6.51$, $p = 0.039$). In contrast, no significant differences were observed for progress feedback ($H = 5.44$, $p = 0.070$), enjoyment ($H = 5.40$, $p = 0.067$), curiosity ($H = 2.84$, $p = 0.242$), ease of control ($H = 1.80$, $p = 0.406$), or clarity of goal ($H = 0.52$, $p = 0.773$). Because multiple constructs were tested, these subgroup comparisons are interpreted as exploratory, and future work may apply formal adjustments for multiple testing when confirming these patterns.

Overall, these results suggest that tablet use frequency is associated with several psychosocial (autonomy, immersion, mastery, and meaning) and selected functional (audiovisual appeal and challenge) dimensions of player experience, while differences in ease of control, clarity of goal, progress feedback, curiosity, and enjoyment were not statistically significant at the 0.05 level in this dataset. Taken together, these findings provide an empirical basis for interpreting how children experience tangible programming games and how prior digital familiarity relates to different dimensions of player experience. The following section discusses these results in relation to previous research and design considerations.

DISCUSSION

OVERVIEW OF KEY FINDINGS

This study was conducted to address the limited empirical understanding of how children experience gameplay when interacting with tangible programming games. Overall, the findings indicate that the TUI-based game generated positive player experiences across functional, psychosocial, and enjoyment dimensions, as measured using the miniPXI, a validated instrument for capturing player experience consequences (Haider et al., 2022; Hartevelde et al., 2020).

From a functional perspective, high scores for audiovisual appeal and progress feedback suggest that visual clarity and explicit system responses effectively supported children's interaction with the game,

in line with prior work on cognitive load and feedback in game-based learning (Chang et al., 2018; Skulmowski & Rey, 2017). At the same time, comparatively lower ease of control scores indicate that tangible interaction may involve an initial adaptation phase, reflecting challenges commonly reported in TUI-based systems that rely on physical input (Marco et al., 2013; Redwan et al., 2025).

In terms of psychosocial experience, high levels of curiosity and immersion point to strong exploratory engagement, while positive autonomy and mastery scores suggest that many children experienced a sense of control and competence during gameplay. However, lower perceived meaning highlights a potential gap between engagement and explicit conceptual interpretation, a pattern consistent with prior research showing that conceptual understanding in early programming activities often develops gradually with appropriate scaffolding (Christie, 2022; Tikva & Tambouris, 2021).

Analysis by tablet-use frequency provides additional insight into how prior digital familiarity relates to player experience. While children with more frequent tablet use tended to report higher scores on several constructs, enjoyment remained high across all groups, including children with limited tablet experience. Taken together, these findings suggest that tangible programming games may support accessible and engaging gameplay experiences for children with diverse levels of digital familiarity, while also revealing design challenges related to control adaptation and the communication of educational meaning.

PLAYER EXPERIENCE DIMENSIONS IN A TANGIBLE PROGRAMMING GAME

The functional outcomes observed in this study can be interpreted as evidence that early programming games for children benefit from interface designs that minimize unnecessary cognitive demands and provide clear, immediate system responses. Research in digital game-based learning has shown that well-designed game environments can support flow and reduce overall cognitive load compared to more traditional learning interactions, particularly when visual structure and feedback help learners stay oriented during tasks (Chang et al., 2018). In embodied learning contexts, measurement work also emphasizes that cognitive demands can be shaped by the coordination of bodily action and perception with learning tasks, which is especially relevant in tangible interaction settings (Skulmowski & Rey, 2017). From this perspective, the high ratings for audiovisual appeal and progress feedback suggest that the game's visual clarity and responsiveness likely helped children form a stable understanding of what was happening during play, thereby supporting short play sessions in which attention and working memory resources are limited.

Progress feedback, in particular, can be discussed not only as usability support but also as a learning-relevant mechanism that encourages iterative reflection. A survey of programming games highlights that many designs prioritize correctness and task completion, while reflection is often under-supported during gameplay (Villareale et al., 2020). In contrast, educational approaches inspired by test-driven development emphasize cycles of "trying, checking, and revising" that move learners from trial and error toward more reflective problem solving (Edwards, 2004). Interpreted through this perspective, strong progress feedback in the present game may have helped children connect action to outcome in a way that supports iterative reasoning, even when the learning goal is embedded in a playful format.

The pattern of challenge and clarity of goal can also be interpreted through challenge-skill alignment. Work on flow and performance anxiety suggests that mismatches between perceived challenge and perceived skill can undermine optimal experience, while balance supports engagement and sustained involvement (Fullagar et al., 2013). Within game-based learning, scaffolding and reward mechanisms have been shown to influence how players approach problem-solving and how dependent they become on support features (C.-T. Sun et al., 2018). Related engagement research also argues that immersive aspects of flow are closely linked to situational interest, while competence-oriented engagement depends on how the game supports learners during tasks (Küli et al., 2021). Taken together, these perspectives help explain why children may report a generally appropriate level of task difficulty

while still exhibiting variability in their experiences. A single difficulty structure can be perceived differently depending on individual skills, strategies, and familiarity with digital interaction patterns.

The comparatively lower ease of control outcomes highlight a recurring design tension in tangible systems. While tangible interfaces promise intuitive, graspable interaction, this advantage can be diminished when the physical input device does not align well with children's motor capabilities or established interaction habits. Foundational work on tangible user interfaces emphasizes the value of coupling digital "bits" with graspable physical objects to enable direct manipulation and embodied engagement (Ishii & Ullmer, 1997). Similarly, embodied interaction theory argues that effective interaction emerges from skilled practice situated in real-world activity, rather than from abstract command execution alone (Dourish, 2001). However, empirical evaluations of tangible systems for children also show that usability depends on carefully integrating system feedback with appropriate facilitation and minimizing friction in physical manipulation (Marco et al., 2013). This supports the interpretation that tangible controllers can enhance engagement while still requiring user-centered refinement to improve controllability and consistency, a point repeatedly emphasized in user-centered design research on tactile and tangible interaction devices (Redwan et al., 2025).

From a psychosocial perspective, the high levels of curiosity and immersion reported by participants suggest that the game environment may support exploratory engagement and focused attention during gameplay. In game-based learning research, curiosity is often associated with intrinsic motivation and willingness to explore alternative strategies, while immersion reflects a state of focused involvement that supports continued engagement over time (Shi & Shih, 2015). Such engagement patterns are closely related to flow-related experiences, particularly the immersive and enjoyment-oriented components of flow that are frequently observed in children's gameplay (Küli et al., 2021). Within this context, tangible interaction may have reinforced experiential engagement by encouraging direct manipulation and physical involvement, thereby helping children remain attentive and motivated during problem-solving activities.

Beyond momentary engagement, autonomy and perceived mastery play critical roles in shaping children's psychosocial experiences in educational programming games. High autonomy scores suggest that children felt they had meaningful control over their actions, while positive mastery perceptions indicate that tasks were often experienced as achievable rather than frustrating. However, these constructs should not be interpreted as indicators of conceptual understanding. Prior research on programming games emphasizes that feeling capable does not necessarily imply that learners develop a clear mental model of underlying programming principles (Villareale et al., 2020). Similarly, educational approaches grounded in reflective practice argue that deeper learning emerges when learners are guided to connect actions, outcomes, and underlying rules through deliberate reflection cycles rather than relying solely on successful task completion (Edwards, 2004). Interpreted in this way, the psychosocial profile observed in this study suggests strong motivational support and also points to a potential gap between experiential success and explicit conceptual meaning.

This interpretation is further reinforced by the comparatively lower scores on perceived meaning. For young learners, especially in playful, tangible environments, educational content may be framed primarily as a game rather than as a representation of formal programming concepts. Previous work has noted that children often interpret programming games from a play-oriented perspective, with conceptual meaning emerging gradually through repeated exposure, external guidance, or explicit instructional prompts (Christie, 2022; Villareale et al., 2020). In this context, the present findings highlight a key psychosocial design challenge: preserving curiosity and immersion while helping children recognize the educational relevance of their actions during gameplay. This balance is particularly important in tangible programming games, where physical interaction can enhance engagement but may also make abstract concepts less immediately visible if not carefully scaffolded. In addition to functional and psychosocial outcomes, the enjoyment dimension provides important insight into the overall gameplay experience.

The enjoyment dimension further complements the functional and psychosocial findings by indicating that participants generally experienced a positive and engaging interaction with the tangible programming game. A high enjoyment score suggests that the combination of tangible manipulation and visual feedback contributed to a playful and accessible gameplay experience. Notably, the consistently positive enjoyment scores across participants align with prior research indicating that tangible interaction can enhance engagement by providing a more concrete and physically intuitive way to interact with programming tasks (Almjally et al., 2020; Melcer & Isbister, 2018). However, variations in enjoyment levels across participants may reflect differences in how easily children adapted to the tangible controller and interpreted the feedback provided during gameplay. This highlights the importance of designing interaction mechanisms that not only support usability but also sustain enjoyment across diverse user backgrounds.

TANGIBLE INTERACTION AND INCLUSIVE PLAYER EXPERIENCE

The group-level patterns by tablet use frequency provide a useful perspective for understanding how prior digital familiarity relates to children's gameplay experiences in tangible programming games. While children with more frequent tablet use tended to report higher scores on several constructs, enjoyment remained consistently high across all groups. Notably, children who rarely used tablets still reported strong enjoyment. However, these observations are based on exploratory subgroup comparisons, and differences in enjoyment across groups did not reach statistical significance ($H = 5.40$, $p = 0.067$). Therefore, the observed pattern should be interpreted cautiously and requires further investigation. This pattern is noteworthy because many educational programming environments implicitly assume familiarity with screen-based interaction conventions, which can shape how easily children enter gameplay and engage with programming tasks (Macrides et al., 2022).

One possible explanation is that tangible interaction reduces reliance on previously learned touchscreen habits and lowers the interactional entry barrier. Foundational work on tangible user interfaces highlights the role of graspable physical objects in supporting direct manipulation and embodied interaction (Dourish, 2001; Ishii & Ullmer, 1997). For children with limited tablet experience, arranging physical blocks may therefore serve as an accessible entry point, enabling engagement through familiar actions such as placing, ordering, and adjusting objects rather than performing abstract digital gestures.

A second explanation relates to novelty and curiosity. When children encounter an interaction modality that differs from everyday screen-based devices, the tangible format may initially amplify interest and enjoyment. Previous research on gamified and playful learning environments has documented a novelty effect in which unfamiliar interaction styles lead to heightened engagement during early exposure (Tsay et al., 2020). Although the present study did not examine changes over time, the consistently high enjoyment reported by children with limited tablet use is compatible with this account. This interpretation reflects an observed tendency rather than a confirmed effect and therefore should be treated as a pattern requiring further validation. Importantly, prior comparative research suggests that enjoyment in tangible programming environments can remain high even when learning gains or performance differ, indicating that enjoyment is not simply a function of prior digital skill (Almjally et al., 2020).

Beyond novelty, the physical nature of tangible interaction may further support enjoyment by making programming gameplay feel more concrete and developmentally appropriate. Reviews of TUIs in early childhood contexts emphasize that physical manipulatives can promote playful engagement and embodiment, supporting motivation even when abstract concepts are still emerging (Baykal et al., 2018; Rodić & Granić, 2022). Empirical studies of educational programming games likewise report that embodied input can enhance enjoyment and reduce intimidation or anxiety associated with programming tasks, particularly for novice learners (Melcer & Isbister, 2018).

Taken together, these interpretations suggest an experience-oriented view of inclusivity in early programming games. Rather than treating prior digital familiarity as a prerequisite for positive engagement, TUI-based designs may serve as accessible entry points that foster enjoyment across diverse backgrounds. This does not eliminate the design challenges identified earlier, particularly those related to ease of control and the communication of educational meaning. Instead, the findings point to a sequencing perspective, in which tangible interaction secures early engagement and enjoyment, while subsequent design features strengthen conceptual understanding through reflection and scaffolding. From this perspective, player experience may serve as a meaningful evaluative lens in relation to accessibility-related considerations in educational programming games, complementing outcome-focused assessments.

IMPLICATIONS FOR DESIGN AND EVALUATION

The findings of this study have several implications for the design and evaluation of educational programming games for children, particularly those employing TUIs. First, the results suggest that enjoyment and psychosocial engagement can be achieved even among learners with limited prior exposure to digital devices. This highlights the importance of designing interaction modalities that do not implicitly privilege digitally experienced users. In early programming contexts, tangible interaction may offer a potentially promising entry point by allowing children to engage through physical manipulation rather than relying solely on abstract interface conventions.

Second, the observed pattern of high engagement alongside lower perceived meaning reinforces the need to distinguish between motivational access and conceptual access in game-based learning designs. While tangible interaction appears effective in supporting curiosity, immersion, and perceived autonomy, these qualities alone do not guarantee that children will explicitly recognize the educational purpose of their actions. From a design perspective, this suggests that engagement-oriented interaction should be complemented by mechanisms that support reflection, such as explicit feedback linking actions to programming concepts or structured opportunities for discussion and interpretation. Rather than reducing playfulness to increase instructional clarity, designers may instead consider sequencing strategies in which engagement is established first and conceptual meaning is gradually foregrounded.

From an evaluation standpoint, the findings underscore the value of incorporating player experience measures alongside learning outcomes when assessing educational programming games. Prior research has often emphasized performance-based indicators, which may overlook how accessible or inclusive an experience feels to different groups of learners. By showing that enjoyment and psychosocial engagement can vary independently from prior digital familiarity, this study supports a broader evaluative perspective in which usability, engagement, and affective experience are treated as meaningful indicators of educational quality. Such an approach is particularly relevant in early programming education, where positive experiences may play a critical role in shaping children's long-term attitudes toward computing.

LIMITATIONS AND FUTURE WORK

Despite the positive findings, this study has several limitations that should be considered when interpreting the results. First, the evaluation relied on a post-test experience-based assessment conducted after a single gameplay session. While this approach is appropriate for capturing immediate player experience, it does not allow conclusions about the stability of enjoyment, engagement, or perceived meaning over time. Consequently, the findings reflect short-term experiential responses rather than longer-term learning trajectories or sustained engagement patterns.

Second, the participants were limited to children aged 6–8 years from a single elementary school. While this age group is an important target audience for introductory programming education, the findings may not generalize to children of other ages or in different educational contexts. Future

work involving more diverse participant groups, age ranges, and educational settings could provide a broader understanding of how tangible programming games are experienced by different learners.

Third, although tablet use frequency was included as an indicator of prior digital familiarity, this measure provides only a limited approximation of children's broader technology experience. Other factors, such as prior exposure to programming activities, gaming habits beyond tablet use, or classroom mediation, were not explicitly controlled and may have influenced individual experiences. Future work could adopt more detailed measures of prior experience to better clarify the role of digital familiarity in shaping gameplay and learning processes.

Fourth, the study focused primarily on player experience outcomes and did not directly assess learning gains or conceptual understanding of programming concepts. While this focus was a deliberate design choice aligned with the study's research objectives, it limits the ability to relate enjoyment and psychosocial engagement to learning effectiveness. Future work could integrate player experience measures with performance-based and qualitative learning assessments to better understand how engagement, perceived meaning, and learning outcomes interact over time.

Finally, the tangible input device examined in this study represents a single design implementation. As suggested by the ease of control findings, different tangible forms, sizes, or affordances may produce different usability and experience profiles. Future work should therefore explore alternative tangible designs and interaction mappings, and further examine the suitability and validation of player experience instruments, such as miniPXI, for use with young learners. Addressing these aspects would strengthen the methodological foundation for evaluating player experience in early programming education.

CONCLUSION

This study examined children's player experience in a tangible programming game, focusing on functional usability, psychosocial engagement, and enjoyment. By applying a validated player experience instrument with children aged 6–8 years, the study provides empirical insight into how young learners experience tangible programming game systems.

This study provides evidence that the tangible programming game examined here was associated with positive immediate player experiences across functional and psychosocial dimensions. Visual clarity and progress feedback played an important role in supporting interaction, while tangible manipulation encouraged curiosity, immersion, and a sense of autonomy during gameplay. At the same time, the results highlight important design challenges, particularly related to ease of control and the communication of educational meaning, indicating that high engagement does not necessarily translate into explicit conceptual understanding.

A noteworthy descriptive observation is that children with less frequent tablet use reported high enjoyment. Because the between-group difference in enjoyment was not statistically significant, this pattern should be interpreted with caution as an exploratory indication that tangible interaction may offer positive gameplay experiences for children with limited prior digital experience. From this perspective, the findings may contribute to existing work on tangible programming games by highlighting player experience as a potential evaluative lens in relation to accessibility-related considerations, rather than focusing exclusively on learning outcomes.

Taken together, this study provides evidence that the tangible programming game examined here was associated with positive immediate player experiences among children aged 6–8 years and highlights the value of using a player experience instrument that was previously validated in game research and adapted for this study. These findings are relevant for researchers, designers, and educators seeking to develop developmentally appropriate programming experiences for young children.

Future work could build on these findings by examining how player experience relates to learning outcomes, comparing tangible and graphical versions of educational programming games, testing tangible programming game systems with more diverse participant groups, and further validating player experience instruments for use with very young learners. Such directions will help clarify how tangible interaction may support engaging and accessible entry points into early programming experiences, particularly in early programming education contexts.

REFERENCES

- Akyaman, S., & Alppay, E. C. (2024). Effects of industrial design properties of game controllers on player experience. *Entertainment Computing*, 50, 100687. <https://doi.org/10.1016/j.entcom.2024.100687>
- Almjally, A., Howland, K., & Good, J. (2020). Comparing TUIs and GUIs for primary school programming. *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* (pp. 521–527). Association for Computing Machinery. <https://doi.org/10.1145/3328778.3366851>
- Baykal, G. E., Alaca, I. V., Yantaç, A. E., & Göksun, T. (2018). A review on complementary natures of tangible user interfaces (TUIs) and early spatial learning. *International Journal of Child-Computer Interaction*, 16, 104–113. <https://doi.org/10.1016/j.ijcci.2018.01.003>
- Borgers, N., Sikkel, D., & Hox, J. (2004). Response effects in surveys on children and adolescents: The effect of number of response options, negative wording, and neutral mid-point. *Quality and Quantity*, 38, 17–33. <https://doi.org/10.1023/B:QUQU.0000013236.29205.a6>
- Chandra, C. E., Timothy, J., & Ramdhan, D. (2025). The effectiveness of serious puzzle games on improving introductory learning of computational thinking skills. *Procedia Computer Science*, 269, 598–607. <https://doi.org/10.1016/j.procs.2025.09.003>
- Chang, C.-C., Warden, C. A., Liang, C., & Lin, G.-Y. (2018). Effects of digital game-based learning on achievement, flow and overall cognitive load. *Australasian Journal of Educational Technology*, 34(4), 155–167. <https://doi.org/10.14742/ajet.2961>
- Christie, S. (2022). Why play equals learning: Comparison as a learning mechanism in play. *Infant and Child Development*, 31(1), e2285. <https://doi.org/10.1002/icd.2285>
- Dourish, P. (2001). *Where the action is: The foundations of embodied interaction*. MIT Press. <https://doi.org/10.7551/mitpress/7221.001.0001>
- Druin, A. (1999). Cooperative inquiry: Developing new technologies for children with children. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 592–599). Association for Computing Machinery. <https://doi.org/10.1145/302979.303166>
- Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, 6(3), 241–252. <https://doi.org/10.2307/1266041>
- Edwards, S. H. (2004). Using software testing to move students from trial-and-error to reflection-in-action. *Proceedings of the 35th SIGCSE Technical Symposium on Computer Science Education* (pp. 26–30). Association for Computing Machinery. <https://doi.org/10.1145/971300.971312>
- Flannery, L. P., Silverman, B., Kazakoff, E. R., Bers, M. U., Bontá, P., & Resnick, M. (2013). Designing ScratchJr: Support for early childhood learning through computer programming. *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 1–10). Association for Computing Machinery. <https://doi.org/10.1145/2485760.2485785>
- Fokides, E. (2017). Students learning to program by developing games: Results of a year-long project in primary school settings. *Journal of Information Technology Education: Research*, 16, 475–505. <https://doi.org/10.28945/3893>
- Fullagar, C. J., Knight, P. A., & Sovern, H. S. (2013). Challenge/skill balance, flow, and performance anxiety. *Applied Psychology*, 62(2), 236–259. <https://doi.org/10.1111/j.1464-0597.2012.00494.x>

- Giannakoulas, A., & Xinogalos, S. (2024). Studying the effects of educational games on cultivating computational thinking skills to primary school students: A systematic literature review. *Journal of Computers in Education*, 11(4), 1283–1325. <https://doi.org/10.1007/s40692-023-00300-z>
- Gouws, L. A., Bradshaw, K., & Wentworth, P. (2013). Computational thinking in educational activities: An evaluation of the educational game Light-Bot. *Proceedings of the 18th ACM Conference on Innovation and Technology in Computer Science Education* (pp. 10–15). Association for Computing Machinery. <https://doi.org/10.1145/2462476.2466518>
- Gris, G., & Bengtson, C. (2021). Assessment measures in game-based learning research. *International Journal of Serious Games*, 8(1), 3–26. <https://doi.org/10.17083/ijsg.v8i1.383>
- Haider, A., Hartevelde, C., Johnson, D., Birk, M. V., Mandryk, R. L., Seif El-Nasr, M., Nacke, L. E., Gerling, K., & Vanden Abeele, V. (2022). miniPXI: Development and validation of an eleven-item measure of the player experience inventory. *Proceedings of the ACM on Human-Computer Interaction*, 6(CHI PLAY), Article 244. <https://doi.org/10.1145/3549507>
- Haider, A., Wallner, G., Gerling, K., & Vanden Abeele, V. (2023). Preliminary study of the performance of the miniPXI when measuring player experience throughout game development. *Companion Proceedings of the Annual Symposium on Computer-Human Interaction in Play* (pp. 56–62). Association for Computing Machinery. <https://doi.org/10.1145/3573382.3616076>
- Haider, A., Wallner, G., Gerling, K., & Vanden Abeele, V. (2024). An investigation of the test-retest reliability of the miniPXI. *Proceedings of the ACM on Human-Computer Interaction*, 8(CHI PLAY), Article 293. <https://doi.org/10.1145/3677058>
- Hall, L., Hume, C., & Tazzyman, S. (2016). Five degrees of happiness: Effective smiley face Likert scales for evaluating with children. *Proceedings of the 15th International Conference on Interaction Design and Children* (pp. 311–321). Association for Computing Machinery. <https://doi.org/10.1145/2930674.2930719>
- Hartevelde, C., Javvaji, N., Machado, T., Zastavker, Y. V., Bennett, V., & Abdoun, T. (2020). Preliminary development and evaluation of the mini player experience inventory (mPXI). *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play* (pp. 257–261). Association for Computing Machinery. <https://doi.org/10.1145/3383668.3419877>
- Hsu, T.-C., Chang, S.-C., & Hung, Y.-T. (2018). How to learn and how to teach computational thinking: Suggestions based on a review of the literature. *Computers & Education*, 126, 296–310. <https://doi.org/10.1016/j.compedu.2018.07.004>
- Ishii, H., & Ullmer, B. (1997). Tangible bits: Towards seamless interfaces between people, bits and atoms. *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems* (pp. 234–241). Association for Computing Machinery. <https://doi.org/10.1145/258549.258715>
- Jamieson, S. (2004). Likert scales: How to (ab)use them. *Medical Education*, 38(12), 1217–1218. <https://doi.org/10.1111/j.1365-2929.2004.02012.x>
- Johnson, D., Gardner, M. J., & Perry, R. (2018). Validation of two game experience scales: The player experience of need satisfaction (PENS) and game experience questionnaire (GEQ). *International Journal of Human-Computer Studies*, 118, 38–46. <https://doi.org/10.1016/j.ijhcs.2018.05.003>
- Kalelioglu, F. (2015). A new way of teaching programming skills to K-12 students: Code.org. *Computers in Human Behavior*, 52, 200–210. <https://doi.org/10.1016/j.chb.2015.05.047>
- Kanika, Chakraverty, S., & Chakraborty, P. (2020). Tools and techniques for teaching computer programming: A review. *Journal of Educational Technology Systems*, 49(2), 170–198. <https://doi.org/10.1177/0047239520926971>
- Kiili, K. J. M., Lindstedt, A., Koskinen, A., Halme, H., Ninaus, M., & McMullen, J. (2021). Flow experience and situational interest in game-based learning: Cousins or identical twins. *International Journal of Serious Games*, 8(3), 93–114. <https://doi.org/10.17083/ijsg.v8i3.462>
- Krestanova, A., Cerny, M., & Augustynek, M. (2021). Review: Development and technical design of tangible user interfaces in wide-field areas of application. *Sensors*, 21(13), 4258. <https://doi.org/10.3390/s21134258>

- Lee, S.-M., Chun, S.-J., Jo, Y., Hong, J.-Y., & Seo, J.-H. (2024). Tangible programming education program to improve collaborative problem-solving (CPS) competency of elementary school students. In J.-C. Hong (Ed.), *New technology in education and training* (pp. 255–266). Springer. https://doi.org/10.1007/978-981-97-3883-0_22
- Lindberg, R. S. N., Laine, T. H., & Haaranen, L. (2018). Gamifying programming education in K-12: A review of programming curricula in seven countries and programming games. *British Journal of Educational Technology*, 50(4), 1979–1995. <https://doi.org/10.1111/bjiet.12685>
- Liu, W., Tan, L., Huang, D., Chen, N., & Liu, F. (2021). When preschoolers use tablets: The effect of educational serious games on children’s attention development. *International Journal of Human–Computer Interaction*, 37(3), 234–248. <https://doi.org/10.1080/10447318.2020.1818999>
- Macrides, E., Miliou, O., & Angeli, C. (2022). Programming in early childhood education: A systematic review. *International Journal of Child-Computer Interaction*, 32, 100396. <https://doi.org/10.1016/j.ijcci.2021.100396>
- Marco, J., Cerezo, E., & Baldassarri, S. (2013). Bringing tabletop technology to all: Evaluating a tangible farm game with kindergarten and special needs children. *Personal and Ubiquitous Computing*, 17(8), 1577–1591. <https://doi.org/10.1007/s00779-012-0522-5>
- Marfisi-Schottman, I., George, S., & Leconte, M. (2019). TurtleTable: Learn the basics of computer algorithms with tangible interactions. In M. Gentile, M. Allegra, & H. Söbke (Eds.), *Games and learning alliance* (pp. 308–317). Springer. https://doi.org/10.1007/978-3-030-11548-7_29
- Melcer, E. F., & Isbister, K. (2018). Bots & (main)frames: Exploring the impact of tangible blocks and collaborative play in an educational programming game. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (pp. 1–14). Association for Computing Machinery. <https://doi.org/10.1145/3173574.3173840>
- Mellor, D., & Moore, K. A. (2014). The use of Likert scales with children. *Journal of Pediatric Psychology*, 39(3), 369–379. <https://doi.org/10.1093/jpepsy/jst079>
- Miljanovic, M. A., & Bradbury, J. S. (2018). A review of serious games for programming. In S. Göbel, A. Garcia-Agundez, T. Tregel, M. Ma, J. B. Hauge, M. Oliveira, T. Marsh, & P. Caserman (Eds.), *Serious games* (pp. 204–216). Springer. https://doi.org/10.1007/978-3-030-02762-9_21
- Molina, A. I., Navarro, C. X., Alarcón, O., & Redondo, M. A. (2025). Tangible user interfaces in computer programming learning: A systematic literature review. *IEEE Access*, 13, 179538–179555. <https://doi.org/10.1109/ACCESS.2025.3621839>
- Nadeem, M., Oroszlanyova, M., & Farag, W. (2023). Effect of digital game-based learning on student engagement and motivation. *Computers*, 12(9), 177. <https://doi.org/10.3390/computers12090177>
- Nielsen, J., & Landauer, T. K. (1993). A mathematical model of the finding of usability problems. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 206–213). Association for Computing Machinery. <https://doi.org/10.1145/169059.169166>
- Pellas, N. (2024). Effects of simulation games on students’ computational thinking and game experience for programming courses in primary school. *Computers in the Schools*, 41(1), 23–50. <https://doi.org/10.1080/07380569.2023.2206825>
- Read, J. C. (2008). Validating the Fun Toolkit: An instrument for measuring children’s opinions of technology. *Cognition, Technology & Work*, 10(2), 119–128. <https://doi.org/10.1007/s10111-007-0069-9>
- Read, J. C., & MacFarlane, S. (2006). Using the fun toolkit and other survey methods to gather opinions in child computer interaction. *Proceedings of the 2006 Conference on Interaction Design and Children* (pp. 81–88). Association for Computing Machinery. <https://doi.org/10.1145/1139073.1139096>
- Redwan, K., Ahmed, M., Sheikh, T. I., Hasan, K. M. S., Sohan, M. F. A. A., & Hasan, K. T. (2025). GlobeStick: Innovating map navigation through tactile interaction and user-centered design. In M. Schrepp (Ed.), *Design, user experience, and usability* (pp. 224–240). Springer. https://doi.org/10.1007/978-3-031-93233-5_16
- Rodić, L. D., & Granić, A. (2022). Tangible interfaces in early years’ education: A systematic review. *Personal and Ubiquitous Computing*, 26, 39–77. <https://doi.org/10.1007/s00779-021-01556-x>

- Shi, Y.-R., & Shih, J.-L. (2015). Game factors and game-based learning design model. *International Journal of Computer Games Technology*, 2015, Article 549684. <https://doi.org/10.1155/2015/549684>
- Skulmowski, A., & Rey, G. D. (2017). Measuring cognitive load in embodied learning settings. *Frontiers in Psychology*, 8, 1191. <https://doi.org/10.3389/fpsyg.2017.01191>
- Sun, C.-T., Chen, L.-X., & Chu, H.-M. (2018). Associations among scaffold presentation, reward mechanisms and problem-solving behaviors in game play. *Computers & Education*, 119, 95–111. <https://doi.org/10.1016/j.compedu.2018.01.001>
- Sun, L., Kangas, M., & Ruokamo, H. (2023). Game-based features in intelligent game-based learning environments: A systematic literature review. *Interactive Learning Environments*, 32(7), 3431–3447. <https://doi.org/10.1080/10494820.2023.2179638>
- Tikva, C., & Tambouris, E. (2021). Mapping computational thinking through programming in K-12 education: A conceptual model based on a systematic literature review. *Computers & Education*, 162, 104083. <https://doi.org/10.1016/j.compedu.2020.104083>
- Tsay, C. H., Kofinas, A. K., Trivedi, S. K., & Yang, Y. (2020). Overcoming the novelty effect in online gamified learning systems: An empirical evaluation of student engagement and performance. *Journal of Computer Assisted Learning*, 36(2), 128–146. <https://doi.org/10.1111/jcal.12385>
- Vanden Abeele, V., Nacke, L. E., Mekler, E. D., & Johnson, D. (2016). Design and preliminary validation of the player experience inventory. *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play. Companion Extended Abstracts* (pp. 335–341). Association for Computing Machinery. <https://doi.org/10.1145/2968120.2987744>
- Vanden Abeele, V., Spiel, K., Nacke, L., Johnson, D., & Gerling, K. (2020). Development and validation of the player experience inventory: A scale to measure player experiences at the level of functional and psychosocial consequences. *International Journal of Human-Computer Studies*, 135, 102370. <https://doi.org/10.1016/j.ijhcs.2019.102370>
- Villareale, J., Biemer, C. F., Seif El-Nasr, M., & Zhu, J. (2020). Reflection in game-based learning: A survey of programming games. *Proceedings of the International Conference on the Foundations of Digital Games* (Article 81). Association for Computing Machinery. <https://doi.org/10.1145/3402942.3403011>
- Wang, X., Xing, Q., Jin, Q., & Wang, D. (2024). “Be a lighting programmer”: Supporting children collaborative learning through tangible programming system. *International Journal of Human-Computer Interaction*, 40(10), 2622–2640. <https://doi.org/10.1080/10447318.2022.2163783>
- Wong-Aitken, D., Rajabi, P., Carpendale, S., & Chilana, P. K. (2023). TangiBooks: Design and creation of paper-based tangibles with embedded electronics for teaching programming concepts. *Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing, Washington, DC, USA*, 12–24. <https://doi.org/10.1109/VL-HCC57772.2023.00010>
- Zhan, Z., He, L., Tong, Y., Liang, X., Guo, S., & Lan, X. (2022). The effectiveness of gamification in programming education: Evidence from a meta-analysis. *Computers and Education: Artificial Intelligence*, 3, 100096. <https://doi.org/10.1016/j.caeai.2022.100096>

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