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Exploring Computational Thinking Concepts in the ”Magic Potion” Game: An Analysis of Student Motivation

Fakhri Aulia Wildan Ramadhan*, Lucky Jopi Husada

Informatics Engineering Education, Universitas Muhammadiyah Surakarta

**Email: a710200064@student.ums.ac.id*

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Abstract

Computational thinking (CT) has emerged as a fundamental twenty-first-century skill; however, its instruction continues to face challenges related to student motivation and engagement. This study aims to explore the computational thinking concepts embedded in the ”Magic Potion” game, a digital adaptation of a Bebras Challenge task, and to analyze students' learning motivation after engaging with the game. Employing a Design and Development Research (DDR) approach, the study was conducted through four phases: needs analysis, game development, implementation with 64 eighth-grade students, and motivation evaluation using the Instructional Materials Motivation Survey (IMMS) based on the ARCS model (Attention, Relevance, Confidence, Satisfaction). The analysis revealed that the game integrates four core CT concepts: abstraction, decomposition, pattern recognition, and algorithmic thinking. The IMMS results yielded an overall mean score of 4.19 (High category), with Attention receiving the highest score (M=4.28, Very High), followed by Satisfaction (M=4.22, Very High), Relevance (M=4.19, High), and Confidence (M=4.08, High). These findings indicate that the ”Magic Potion” game not only effectively integrates CT concepts but also generates positive motivational responses from students, particularly in capturing attention and providing learning satisfaction. This study contributes to the development of game-based learning media for CT and demonstrates the potential of adapting Bebras tasks as motivating instructional resources. Limitations include the sample being restricted to a single school and the one-shot case design without a control group; therefore, future research is recommended to employ experimental designs with broader samples and to directly measure gains in CT competencies.

1 Introduction

Computational thinking (CT) has emerged as a fundamental skill for everyone in the twenty-first century, extending far beyond the boundaries of computer science. Since Wing's (2006) seminal article positioned CT as a universal competency that ”involves solving problems, designing systems, and understanding human behavior by drawing on the concepts fundamental to computer science” , researchers, policymakers, and educators have increasingly recognized its importance in preparing students for a technology-driven world . Wing famously argued that CT should be added to every child's analytical ability alongside reading, writing, and arithmetic . This recognition has led to the integration of CT into school curricula across numerous countries, with initiatives ranging from standalone computer science courses to cross-curricular embedding

of CT concepts . As the World Economic Forum projects that half of all employees will require reskilling due to technological advancements, the development of CT competencies has become an educational priority .

Despite widespread consensus on the importance of computational thinking, the field continues to grapple with diverse definitions and conceptual frameworks. Brennan & Resnick (2012) proposed one of the most influential frameworks, dividing CT into three key dimensions: computational concepts (fundamental programming ideas such as loops and conditionals), computational practices (processes of thinking and learning through problem-solving), and computational perspectives (understandings of oneself and the technological world). Other scholars have offered complementary perspectives: Grover & Pea (2013) described CT as encompassing abstractions and pattern generalizations, systematic information processing, algorithmic thinking, structured problem decomposition, conditional logic, efficiency considerations, debugging, and iterative thinking. Shute et al. (2017) synthesized these perspectives to define CT as ”the conceptual foundation required to solve problems effectively and efficiently (i.e., algorithmically, with or without the assistance of computers) with solutions that are reusable in different contexts”, categorizing CT into decomposition, abstraction, algorithms, debugging, iteration, and generalization. More recently, Tang et al. (2020) highlighted an essential distinction between definitions focusing on CT as programming and computing versus those emphasizing CT as competencies needed for both domain-specific knowledge and general problem-solving. This conceptual diversity, while challenging, reflects the richness of CT as a boundary object adaptable across different educational contexts.

The integration of CT into educational practice faces several significant challenges. One primary obstacle is the shortage of teachers with expertise in CT, necessitating substantial investment in professional development programs. Additionally, educators must overcome the fear of failure among both students and teachers, as CT inherently involves experimentation, iteration, and learning through setbacks. Perhaps most fundamentally, there is limited consensus regarding how CT should be operationalized and assessed across different educational levels and subject areas. Researchers have raised questions about how to define CT as a key skill, what its characterizing features are, how it relates to programming on one hand and digital literacy on the other, and how teachers should be prepared to integrate it into their teaching practice. These challenges underscore the need for engaging, accessible instructional materials that can introduce CT concepts without requiring extensive teacher expertise or prior programming knowledge from students.

Game-based learning (GBL) has emerged as a promising approach to address these challenges by providing interactive, motivating environments for developing computational thinking skills. Digital game-based learning (DGBL) refers to the use of digital systems that incorporate games or game elements to motivate and enhance learning. Proponents argue that DGBL facilitates knowledge acquisition while fulfilling learners' psychological needs for competence, autonomy, and relatedness. Multiple studies have demonstrated the potential of game-based approaches for teaching CT, as games can embed problem-solving within engaging narratives and provide immediate feedback that supports iterative learning. For instance, role-play-based micro-game strategies have been shown to significantly improve students' CT skills, particularly in the dimensions of computational concepts and computational practices, while also enhancing learning engagement and motivation. However, researchers note a scarcity of experimental studies examining the impact of DGBL on CT development and student motivation, highlighting the need for further investigation into how specific game designs influence learning outcomes.

The *Bebras Challenge* represents an internationally recognized initiative that provides authentic, well-designed CT problems adaptable for GBL. Formulated in 2004 by Professor Valentina Dagiene from the University of Vilnius, the *Bebras Challenge* aims to encourage CT among students aged 8 to 18. The challenge has grown to include over 60 countries with more than 2.9 million students participating worldwide. Bebras tasks are designed to be fun, engaging problems based on concepts that computer scientists enjoy solving, requiring logical thinking that can be applied without prior knowledge of computational thinking. These tasks promote problem-solving skills and informatics concepts including decomposition of complex tasks into simpler components, algorithm design, pattern recognition, pattern

generalization, and abstraction. The accessibility of *Bebras* problems, requiring no programming experience while still engaging core CT competencies, makes them ideal candidates for adaptation into interactive learning games that can introduce computational thinking to diverse student populations.

Despite the potential of adapting Bebras tasks into GBL environments, limited research has examined how such adaptations influence student motivation. The IMMS, developed by Keller based on the Attention, Relevance, Confidence, Satisfaction (ARCS) model of motivation, provides a validated instrument for assessing the motivational characteristics of learning activities (Loorbach et al., 2015). The ARCS model posits that instructional materials must capture learners' attention, demonstrate relevance to their needs and goals, build confidence in their ability to succeed, and promote satisfaction with the learning experience. Research has shown that the extent and type of educational scaffolding significantly impact the motivational effectiveness of instructional materials, and that IMMS scores demonstrate good reliability and relations with other measures of motivation and learning outcomes . However, the application of IMMS to evaluate game-based adaptations of Bebras tasks remains underexplored, representing a gap in understanding how these internationally recognized CT problems can be transformed into motivating learning experiences.

The present study addresses this gap by exploring computational thinking concepts embedded in the "*Magic Potion*" game, a digital adaptation of a *Bebras Challenge* task, and analyzing student motivation following gameplay. The game presents students with a puzzle involving glasses, five of which contain magical fertilizers with specific effects on flowers (double petals, leaf growth, wavy stems, white petals, or black centers), while one glass contains only water with no effect. Through three experiments combining different glasses, students must apply logical reasoning to identify which glass contains water, thereby engaging core CT competencies including abstraction, decomposition, pattern recognition, and algorithmic thinking. This study aims to answer the following research questions: (1) How are computational thinking concepts manifested in the "*Magic Potion*" game adapted from a Bebras Challenge task? and (2) What are students' motivational responses to the game as measured by the IMMS across the ARCS dimensions of attention, relevance, confidence, and satisfaction? By examining both the CT concepts embedded in game mechanics and the motivational outcomes of gameplay, this research contributes to understanding how Bebras task adaptations can serve as effective, motivating introductions to computational thinking for diverse learners.

2 Method

This study employed Design and Development Research (DDR), a systematic research approach focused on creating new knowledge and validating existing practices through the development of products, tools, or models. Richey & Klein (2014) defined DDR as "the systematic study of design, development, and evaluation processes with the aim of establishing an empirical basis for the creation of instructional and non-instructional products and tools and new or enhanced models that govern their development". This approach was selected as it aligns with the study's objective to develop the educational game as a learning medium for CT and to evaluate its impact on student motivation.

The study adapted the DDR framework proposed by Richey & Klein (2014) and implemented it across four main phases, as illustrated in Figure 1. These phases included: (1) needs analysis, (2) game development based on the analysis findings, (3) implementation of the game as a learning medium through pilot testing with eighth-grade students, and (4) evaluation of student learning motivation using the Instructional Materials Motivation Survey (IMMS). This approach is consistent with other educational game development research that has adapted DDR methodology.

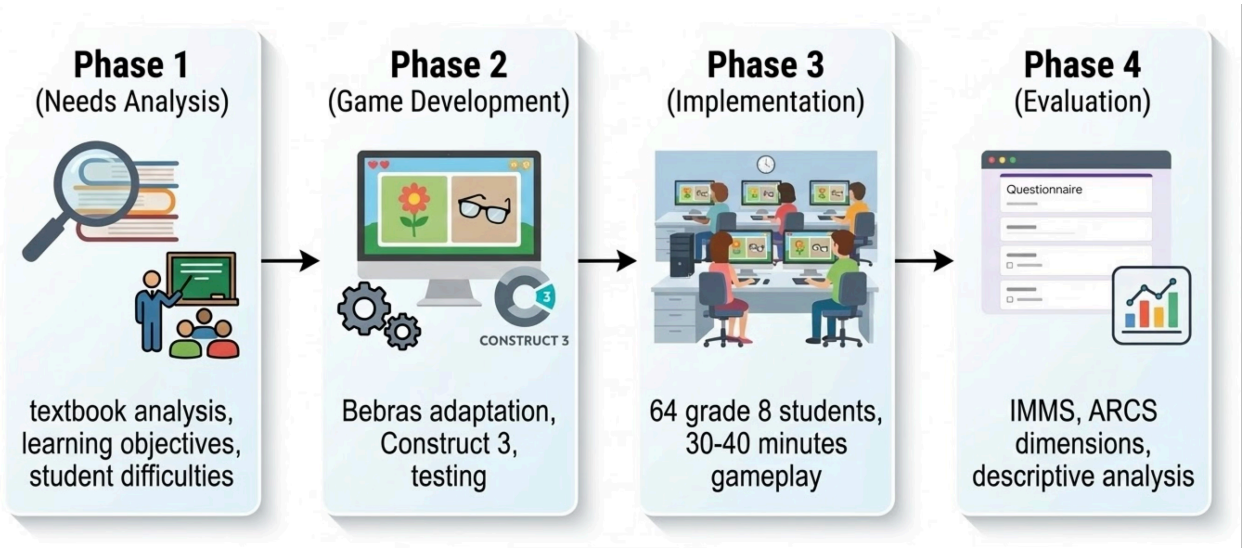

Figure 1: Research phases

2.1 Research Procedure

2.1.1 Phase 1: Needs Analysis

The initial phase of this study began with a comprehensive needs analysis to identify problems and potential for developing the game. The needs analysis was conducted through three approaches. First, textbook analysis was carried out by examining eighth-grade informatics textbooks used in schools, particularly those related to CT concepts. The analysis revealed that although CT concepts have been introduced in the curriculum, their presentation tends to be textual and lacks interactivity. Second, analysis of learning objectives was conducted by reviewing the core competencies that students must achieve related to logical thinking, problem decomposition, pattern recognition, and algorithmic thinking skills. Third, identification of student difficulties was conducted through informal interviews with informatics teachers and initial observation of the learning process. It was found that students experienced difficulties understanding abstract computational thinking concepts when presented through lectures and textbooks, and tended to become bored quickly with conventional learning media. These findings reinforced the need for alternative learning media that are more interactive and motivating, such as educational games, which have been proven effective in enhancing understanding of abstract concepts and student engagement .

2.1.2 Phase 2: Game Development

Based on the needs analysis findings, the game was developed as a digital adaptation of a *Bebras Challenge* task. *Bebras* tasks were selected because they are internationally recognized instruments specifically designed to develop and measure students' CT abilities through contextual and engaging problem-solving. The development process began with analysis of the original *Bebras* problem, which presents a logical puzzle involving six glasses (A-F) containing five magical fertilizers with distinct effects on flowers, and one glass containing only water with no effect. Students must determine which glass contains water by conducting three experiments with different glass combinations.

The game was developed using *Construct 3*, an HTML5-based game development platform that enables the creation of interactive games without requiring advanced programming skills. *Construct 3* was selected for its ability to produce games that can run on multiple platforms (desktop and mobile) and its ease in implementing the drag-and-drop mechanics that form the core interaction in the game.

The development process included designing an intuitive user interface (UI) and user experience (UX), creating visual assets (flower characters, glasses, change animations), implementing game mechanics (drag-

and-drop of glasses onto flowers, experiment logic), and conducting internal testing to ensure functionality. The game was designed with bright colors and engaging animations to capture students' attention, following effective educational game design principles. Prior to pilot testing, the game underwent alpha testing by the research team and limited beta testing with five students to ensure clarity of instructions, appropriate difficulty level, and absence of technical bugs.

2.1.3 Phase 3: Game Implementation as Learning Media

The third phase involved game implementation through pilot testing with eighth-grade students. Eighth grade was selected based on the consideration that students at this level possess sufficient logical thinking abilities to solve the game's challenges, yet remain at a cognitive developmental stage responsive to innovative learning media.

The pilot testing was conducted in the school's computer laboratory over two days. A total of 64 students participated in gameplay sessions lasting 30-40 minutes. Prior to starting, students received brief instructions about the game's purpose and how to play it. During the sessions, students played independently, conducting experiments by dragging and dropping glass combinations onto flowers, observing resulting changes, and using logical reasoning to deduce which glass contained water. No intervention or guidance was provided by researchers during gameplay to ensure that the student experience authentically represented interaction with the game. This approach aligns with game-based learning principles emphasizing independent exploration and discovery.

2.1.4 Phase 4: Evaluation of Learning Motivation

Immediately after completing gameplay sessions, students were asked to complete the IMMS to evaluate their learning motivation after using the game. The IMMS was selected because it is a validated instrument widely used in game-based learning research to measure students' motivational responses to instructional materials. The questionnaire was administered using Google Forms, and students accessed it through a provided link. Questionnaire completion took approximately 10-15 minutes. The collected data were then exported for descriptive statistical analysis.

2.2 Participants

The participants in this study were 64 eighth-grade students. Participants were selected using purposive sampling, with inclusion criteria being students enrolled at the school and willing to participate in the study. As shown in Table 1, the majority of participants (n=58, 90.6%) were aged 13-14 years, while 6 participants (9.4%) were aged 15-16 years. Regarding prior experience with similar educational games, 33 participants (51.6%) reported having played similar educational games before, while 31 participants (48.4%) reported no prior experience with such games.

Table 1: Participant demographics

Demographic Characteristic	Category	Frequency (n)	Percentage (%)
Age	13-14 years	58	90.6
	15-16 years	6	9.4
Prior experience with similar educational games	Yes	33	51.6
	No	31	48.4

All participants were informed about the purpose of the study and the voluntary nature of their participation. Informed consent was obtained from both the school administration and the students' parents or legal guardians prior to data collection, in accordance with ethical research practices involving minors.

2.3 Instrument

The primary instrument used in this study was the IMMS, based on the ARCS model of motivation (Attention, Relevance, Confidence, Satisfaction). The IMMS is a 36-item instrument designed to measure students' motivational reactions to instructional materials. For this study, the instrument was adapted to the context of the "*Magic Potion*" game and translated into Indonesian using a back-translation procedure to ensure conceptual equivalence. The adapted version consisted of 26 items, with items distributed across the four ARCS dimensions as follows: 7 items for Attention, 6 items for Relevance, 6 items for Confidence, and 7 items for Satisfaction .

Each item was rated on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The instrument was designed with all items positively framed to facilitate interpretation for the target age group. The complete list of items, organized by ARCS dimension, is presented in Table 2.

Table 2: IMMS Items by ARCS Dimension

Dimension	Code	Item Statement
Attention	A1	This "Magic Potion" educational game made me more interested in learning about computational thinking.
	A2	The design of this application attracted my attention.
	A3	I felt curious and wanted to know more when using this educational game.
	A4	Interacting with this educational game made me more focused while learning.
	A5	Interactive features such as drag and drop and animations made learning more interesting.
	A6	I did not feel bored when using this educational game.
	A7	The display and colors of this educational game made learning more visually interesting.
Relevance	R1	The content in this educational game is relevant to the learning material.
	R2	I feel that using this educational game can help me understand computational thinking concepts better.
	R3	The information about computational thinking presented in this educational game matches my learning needs.
	R4	This educational game helps me understand abstract concepts about computational thinking that are difficult to learn from books.
	R5	I feel that learning using this educational game is directly related to my learning goals.
	R6	I can connect what I learned from this educational game with what I have learned in class.
Confidence	C1	I feel confident that I can understand computational thinking concepts after using this educational game.
	C2	This educational game helped me feel more confident in learning computational thinking material.
	C3	I feel capable of completing tasks or quizzes related to computational thinking material after using this educational game.
	C4	The instructions and guidance in this educational game are easy to understand and made me feel confident in using it.
	C5	I feel confident that I can remember information about computational thinking better after using this educational game.
	C6	I feel that this educational game makes learning about computational thinking easier compared to learning from books.

Dimension	Code	Item Statement
Satisfaction	S1	I am satisfied with the learning experience using the ”Magic Potion” educational game.
	S2	I felt happy using this educational game to learn about computational thinking material.
	S3	I want to use this educational game again in the future to learn other informatics concepts.
	S4	I feel that this educational game provides a different and more enjoyable learning experience compared to regular learning methods.
	S5	I am satisfied with how this educational game presents information and animations about computational thinking concepts.
	S6	I feel that using this educational game made learning more enjoyable and motivated me to study harder.
	S7	I am satisfied with the ease of navigation and control of this educational game.

3 Results and Discussion

3.1 The Developed Game: ”Magic Potion”

The "*Magic Potion*" game was successfully developed as a digital adaptation of a *Bebras Challenge* task designed to introduce CT concepts to eighth-grade students. The game was developed using Construct 3, an HTML5-based game development platform, and features an intuitive drag-and-drop interface that allows students to conduct experiments by combining different glasses of magical fertilizers and observing their effects on a flower.

Figure 2 presents a screenshot of the main gameplay interface in its initial state, before any experiments have been conducted. As shown in the figure, the game interface consists of several key components designed to facilitate student engagement with CT concepts.

The interface displays a score counter at the top left corner, initially set to 0, which tracks student progress throughout the gameplay. Navigation buttons labeled "*Kembali ke Menu*" (Back to Menu) and "*Lihat Pertanyaan*" (View Question) are positioned at the top right, allowing students to return to the main menu or review the problem statement as needed.

The central area of the screen contains the primary instructional prompt: "*Lakukanlah percobaan dengan menuangkan gelas ramuan ke bunga kemudian perhatikan setiap perubahan! Ramuan akan bekerja ketika 3 jenis ramuan dituangkan*" (Conduct experiments by pouring the potion glasses onto the flower and observe each change! The potion will work when 3 types of potions are poured). This instruction clearly communicates the game's core mechanics, students must combine three different glasses to observe the combined effects of the magical fertilizers.

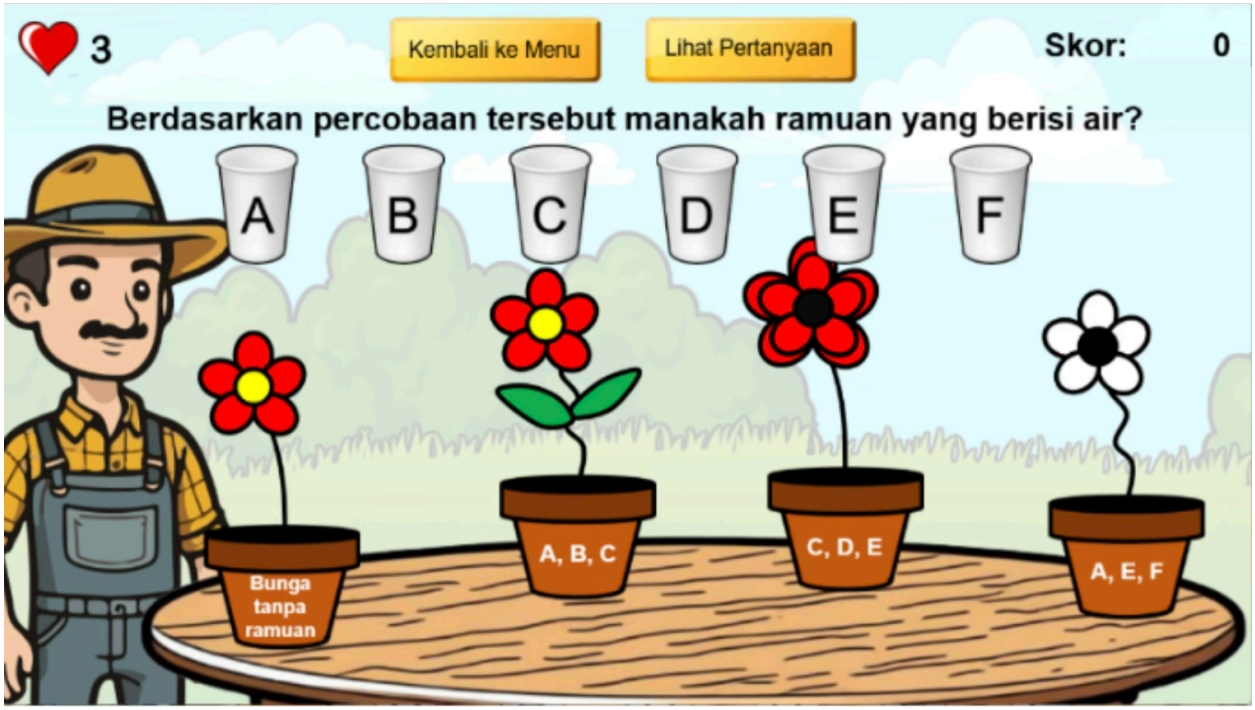

Figure 2: Screenshot of the ”Magic Potion” game interface

Below this instruction, two flowers are displayed side by side. The left flower is labeled ”*Bunga tanpa ramuan*” (Flower without potion) and represents the baseline state of the flower with no fertilizers applied. This original flower exhibits the standard appearance: a single layer of red petals, a yellow center, straight green stems, and no additional leaves. The right flower is currently identical to the left flower, indicating that no experiments have yet been performed. This blank canvas will transform as students apply different combinations of glasses, providing immediate visual feedback that is essential for the logical reasoning process.

At the bottom of the screen, six glasses labeled A through F are arranged in two rows. Each glass contains either a magical fertilizer with specific effects or plain water with no effect. Students can click and drag these glasses to pour their contents onto the flower. When three glasses are combined, the flower on the right will transform to display the cumulative effects of the fertilizers contained in those glasses.

The game design requires students to discover through experimentation which glasses produce which effects. By systematically testing different combinations, particularly the three prescribed experiments from the original Bebras task (A+B+C, A+D+E, and C+D+F), students can observe patterns of change and use logical deduction to identify the single glass that contains only water and produces no effects whatsoever.

The ”*Magic Potion*” game was designed to engage students in four core computational thinking concepts as defined by Brennan & Resnick (2012) and Shute et al. (2017). Table 3 presents the mapping between game mechanics and CT concepts.

Table 3: Computational Thinking Concepts in the ”Magic Potion” Game

CT Concept	Definition	Manifestation in Game Mechanics
Abstraction	Identifying and focusing on relevant information while ignoring irrelevant details	Students must focus on the five specific flower characteristics that change (double petals, leaf growth, wavy stems, white petals, black center) while ignoring other visual aspects of the flower. The game simplifies the complex problem into five binary variables (present/absent) for each characteristic.

CT Concept	Definition	Manifestation in Game Mechanics
Decomposition	Breaking down complex problems into smaller, manageable parts	The overall problem of identifying one water glass among six is broken down into three smaller experiments, each testing a different combination of three glasses. Students analyze each experiment separately before synthesizing the results.
Pattern Recognition	Identifying similarities, differences, and regularities in data	Students must recognize patterns across experiments. For example, if a characteristic appears in experiments involving glass A but not in experiments without A, they can infer that characteristic belongs to glass A. This requires comparing results across all three experiments to identify which glasses consistently produce which effects.
Algorithmic Thinking	Developing step-by-step solutions or logical rules to solve problems	Students must develop a logical reasoning process to eliminate possibilities and deduce the water glass. This involves creating mental "if-then" rules: "If characteristic X appears in experiment 1 and 2 but not 3, then it must come from a glass shared by experiments 1 and 2 but not 3."

The game design intentionally avoids providing explicit instructions on how to solve the puzzle, requiring students to discover and apply these CT concepts independently through exploration and experimentation. This approach aligns with constructivist learning principles that emphasize knowledge construction through active engagement and is consistent with effective game-based learning design that promotes discovery learning.

3.2 Motivational Evaluation

Following gameplay, all 64 participants completed the adapted 26-item IMMS. Descriptive statistical analysis was conducted to calculate mean scores and standard deviations for each of the four ARCS dimensions. Table 4 presents the overall results.

Table 4: Mean scores for ARCS dimensions

Dimension	Number of Items	Mean (M)	Standard Deviation (SD)	Interpretation
Attention	7	4.28	0.47	Very High
Relevance	6	4.19	0.51	High
Confidence	6	4.08	0.58	High
Satisfaction	7	4.22	0.49	Very High
Overall	**26**	**4.19**	**0.51**	**High**

The overall mean score of 4.19 (High category) indicates that students demonstrated positive motivational responses to the game across all four ARCS dimensions. Attention received the highest score (M = 4.28, Very High), suggesting that the game's interactive features and visual design successfully captured student interest. The particularly high score for item A1 ("This game made me more interested in learning about computational thinking," M = 4.41) indicates that the game stimulated broader interest in the subject matter beyond gameplay itself.

Satisfaction also scored in the Very High range (M = 4.22), with students reporting happiness during gameplay (S2: M = 4.30) and preference over regular learning methods (S4: M = 4.28). This suggests the game successfully addressed the affective dimension of learning, which is closely linked to intrinsic motivation and continued engagement (Keller, 2010; Ryan et al., 2006).

Relevance scored in the High range (M = 4.19), with students perceiving the game as effective for understanding CT concepts (R2: M = 4.30) and helpful for grasping abstract ideas difficult to learn from

books (R4: M = 4.23). The slightly lower score for connecting game learning to classroom instruction (R6: M = 4.09) suggests a need for more explicit integration between game-based learning and formal curriculum.

Confidence received the lowest score among the four dimensions (M = 4.08), though still in the High category. While students felt confident in understanding CT concepts after gameplay (C1: M = 4.22), they were slightly less confident about remembering information (C5: M = 4.03) and completing future tasks (C3: M = 4.06). This indicates a need for follow-up activities to reinforce and extend GBL.

3.3 Discussion

The findings of this study demonstrate that the "*Magic Potion*" game successfully integrates four core CT concepts into an engaging digital learning environment adapted from a *Bebras Challenge* task. This integration is particularly significant because it provides students with concrete, observable experiences of abstract CT concepts that are often difficult to grasp through traditional instructional methods (Grover & Pea, 2013). The visual nature of the game, where students can directly see the effects of combining different glasses on flower characteristics, makes the abstraction process tangible and accessible. This aligns with Gee's (2003) argument that well-designed games can situate learning in meaningful contexts, allowing students to develop understanding through active exploration rather than passive reception of information. The game's requirement that students conduct three distinct experiments before synthesizing their findings naturally scaffolds the decomposition process, helping students recognize that complex problems become manageable when broken into smaller components, a fundamental insight in computational thinking (Wing, 2006).

The motivational responses captured by the IMMS reveal that students found the game highly engaging across all four ARCS dimensions, with particularly strong results for Attention and Satisfaction. The mean score of 4.28 for Attention, categorized as Very High, suggests that the game's interactive drag-and-drop mechanics, colorful visual design, and puzzle-based format successfully captured and maintained student interest throughout the learning experience. This finding is consistent with research demonstrating that GBL environments can enhance attention through immediate feedback and aesthetically pleasing designs (Shaheen et al., 2023). Notably, the highest-scoring item within the Attention dimension measured increased interest in learning about computational thinking itself, indicating that the game's motivational impact extended beyond mere enjoyment during gameplay to stimulate broader curiosity about the subject matter, a key goal of effective educational game design.

The Very High satisfaction score (M = 4.22) further reinforces the game's motivational effectiveness, with students reporting happiness during gameplay and expressing preference for this approach over regular learning methods. This affective response is crucial because satisfaction is closely linked to intrinsic motivation and the likelihood of continued engagement with learning materials (Keller, 2010). Ryan et al. (2006) demonstrated that game-based experiences satisfying learners' psychological needs for competence, autonomy, and relatedness generate greater intrinsic motivation, and the current findings suggest that "*Magic Potion*" successfully addresses these needs by providing students with autonomy to conduct experiments independently and competence through successful problem-solving.

The Relevance dimension, scoring in the High range (M = 4.19), indicates that students perceived the game as connected to their learning needs and goals. Students particularly recognized the game's effectiveness for understanding CT concepts (R2) and its value in making abstract ideas accessible compared to textbook learning (R4). However, the slightly lower score for connecting game learning to classroom instruction (R6) highlights an important consideration for implementation. As Hsu et al. (2018) emphasize, GBL should be integrated into broader instructional sequences rather than used as standalone activities. Teachers might enhance relevance by explicitly facilitating discussions that help students connect their game experiences to formal curriculum objectives, thereby maximizing the transfer of learning from game contexts to academic understanding.

The Confidence dimension, while still in the High range (M = 4.08), received the lowest scores among the four ARCS dimensions. Students expressed confidence in understanding CT concepts immediately after

gameplay (C1) but were somewhat less certain about their ability to remember information and complete future tasks related to CT. This pattern suggests that while the game effectively supports initial concept acquisition, students may need additional scaffolding to consolidate learning and build confidence in long-term retention and application. Yang et al., (2024) similarly found that confidence in game-based learning environments can be influenced by factors such as difficulty level and feedback quality. For the "*Magic Potion*" game, incorporating follow-up activities such as guided reflection, similar problem-solving exercises, or explicit discussion of solution strategies could help bridge the gap between gameplay and sustained confidence in CT abilities.

The successful adaptation of a Bebras Challenge task into an engaging, motivating game has broader implications for computational thinking education. The international Bebras community has developed hundreds of well-designed tasks that challenge students to think computationally without requiring programming knowledge (Dagiene & Stupuriene, 2016). Adapting these tasks into interactive games could significantly expand access to CT education by providing engaging, developmentally appropriate learning materials for diverse student populations. Moreover, the high motivational scores across all ARCS dimensions suggest that game-based approaches can address the affective barriers, such as intimidation or perceived difficulty, that often accompany CT instruction. As computational thinking becomes increasingly recognized as a fundamental skill for all students in the twenty-first century (Wing, 2006), developing engaging instructional materials that appeal to diverse learners will be essential for equitable CT education. The "*Magic Potion*" game demonstrates that thoughtfully designed game adaptations of Bebras tasks can effectively serve this purpose, generating positive motivational responses while simultaneously engaging students in authentic CT practices.

4 Conclusion

This study demonstrates that the "*Magic Potion*" game effectively integrates core CT concepts into an engaging learning experience that generates positive motivational responses from eighth-grade students. The game's design successfully translates a text-based logical puzzle into an interactive visual environment where students can actively experiment, observe outcomes, and apply deductive reasoning, thereby making abstract CT concepts tangible and accessible. The high motivational scores across all four ARCS dimensions, particularly Attention (M = 4.28) and Satisfaction (M = 4.22), provide empirical evidence that game-based adaptations of *Bebras* tasks can serve as effective instructional materials that not only introduce computational thinking but also foster positive attitudes toward learning these essential skills. These findings contribute to the growing body of research supporting game-based learning as a viable approach for CT education, particularly for addressing the affective barriers that often hinder student engagement with computational concepts.

Despite these promising results, this study has several limitations that should be acknowledged. First, the sample was limited to 64 students from a single school, which may restrict the generalizability of the findings to broader populations with different demographic characteristics or educational contexts. Second, the study employed a one-shot case design without a control group or pre-test measurement, making it impossible to determine causal relationships between game engagement and motivational outcomes or to assess actual gains in CT abilities. Additionally, the study did not examine how individual differences such as prior gaming experience, gender, or academic achievement might influence motivational responses to the game.

Future research should address these limitations through more rigorous experimental designs that include control groups, pre-test and post-test measurements of both motivation and CT skill development, and longitudinal follow-up to assess retention and sustained engagement. Studies with larger and more diverse samples across multiple schools and grade levels would enhance the generalizability of findings and allow for examination of how demographic factors moderate game effectiveness. Researchers should also consider incorporating qualitative methods such as interviews or think-aloud protocols to gain deeper understanding of how students reason through the puzzle and what aspects of game design most strongly

influence their motivational experience. Finally, investigating the adaptation of other Bebras tasks into game formats could establish design principles for transforming a wider range of CT problems into engaging digital learning experiences, ultimately contributing to a comprehensive game-based curriculum for computational thinking education.

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