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Evaluating Interactive Tasks through the Lens of Computational and Algebraic Thinking, Interactivity Types, and Multimedia Design Principles

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Abstract. This study investigates student engagement within an online assessment environment, focusing on the interplay between interactivity types, and multimedia design. We analyzed (1) descriptive patterns of student engagement and performance, (2) time-on-task in relation to interactivity type of tasks, (3) the frequency and distribution of multimedia design principles (e.g., contiguity, modality) across tasks designed to elicit computational and algebraic thinking, and (4) the correlation between the application of these principles and students' average scores. Findings reveal distinct engagement patterns and performance levels across task types. Time spent varied significantly by interactivity, with certain types eliciting more engagement. Specific multimedia principles were more prevalent in particular tasks, and correlational analysis indicated relationships between the application of certain design principles and student performance outcomes. These insights contribute to a more nuanced understanding of how interactive design and multimedia integration can influence learning in computationally and algebraically rich online environments.

Keywords: interactive tasks, multimedia principles, computational thinking, algebraic thinking.

1. Introduction

The modern era in which we live differs significantly from the past, and hence, there are substantial differences in the skills that individuals are expected to possess. In today's competitive world, international non-governmental organizations such as the World Economic Forum (WEF) regularly update the 21st-century skills which have been frequently identified and featured in the WEF's Future of Jobs reports (World Economic

Forum, 2020). Some of these skills have attracted scholars' attention, with Computational Thinking (CT) as one of these crucial key skills (Agbo *et al.*, 2023; Curzon *et al.*, 2009; Dede *et al.*, 2013; Papadakis, 2022; Voogt *et al.*, 2015; Yang *et al.*, 2023). CT is a term used to define the ability to perform logical reasoning and algorithmic thinking (Denning, 2009). Not just computer scientists, but individuals from various disciplines should possess CT skills (Wing, 2006). CT is said to encompass a set of mental processes, algorithms, and solutions utilized in formulating problems (Grover & Pea, 2013). From a wider perspective, the International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (2011) formulated an operational definition for CT, where they included core skills such as problem solving, decomposition, abstraction, algorithm design and pattern recognition.

While the definitions of CT have varied over time, the consensus is that it is a particularly significant skill for today's world. This disposition leads to the question: "What makes CT one of the most important skills of the 21st century?". Promoting CT skills is essential in educational settings since these skills may serve as a catalyst for learners to understand effective use of technology for solving real-life problems. For example, the ISTE and CSTA (2011) suggested that CT can enhance students' academic performance and better prepare them to join today's competitive workforce. Additionally, Gülbahar *et al.* (2019) argued that CT can expand students' thinking horizons, whilst Tripon (2022) opined that CT can enhance students' lifelong learning skills. Furthermore, Korkmaz and Bai (2019) emphasised that CT is a critical factor in shaping students' attitudes toward science and technology. Numerous studies in the literature have emphasised the significance of CT skills and their implications. The ISTE and CSTA (2011) underlined the existence of a close link between CT and algorithmic and arithmetic thinking. Additionally, Shang *et al.* (2023) revealed a positive relationship between CT and students' self-efficacy, while Polat and Yilmaz (2022) highlighted the correlation between CT and academic achievement.

All of these research studies provided evidence that CT is an important skill that every child has to learn. Based on this fact, numerous research studies have revealed the effect of different plugged and unplugged pedagogical approaches in teaching-learning processes. Although a number of tools exist that could be utilized in accordance with this purpose, the researchers agreed on the use of tasks from Bebras Challenge as the subject of inquiry in the current study, due to its international impact and role on society (`https://www.bebras.org/`).

Computational thinking (CT) is a problem-solving process that involves formulating problems in a way that enables us to use computer-based tools and techniques to help solve them. It's not just about programming, but rather a set of cognitive skills and approaches applicable across many disciplines. The most commonly cited elements of computational thinking include: algorithm design (developing step-by-step procedures or rules to solve a problem), decomposition (breaking down a complex problem into smaller, more manageable parts), pattern recognition (identifying similarities and recurring structures within problems or data), abstraction (focusing on the essential information while ignoring irrelevant details), and evaluation (assessing the effectiveness and efficiency of a solution).

On the other hand, Algebraic Thinking (AT) is a way of thinking about mathematical situations that focuses on generalizing relationships, identifying patterns, and representing these relationships using symbols. It is about moving beyond just calculating with specific numbers to understanding the underlying structure and properties of mathematical operations and systems. AT comprises four thinking strands (Pitta-Panzazi *et al.*, 2020): generalized arithmetic, functional thinking, modeling languages, and algebraic proof (i.e., abstract algebra). AT includes a shift of attention from the result to the process in problem-solving situations (Malara & Navarra, 2018) where some ideas merge and overlap with CT. So, we can talk about some shared features in CT and AT, as follows:

- Algorithmic thinking algorithm design.
- Problem-solving process, abstraction skills.
- Concepts of equality, variable, algorithm and function.
- Defining patterning, generalization and parametrization.

The assessment of computational and algebraic thinking within interactive tasks should consider several key dimensions. Firstly, it should evaluate students' mastery of algorithms, specifically their capacity to comprehend, execute, and create algorithmic procedures, encompassing skills such as decomposition into smaller steps and generalization to broader contexts. Secondly, it needs to gauge their proficiency in problem solving and working with data, including their abilities to analyze, represent in meaningful ways, and derive insights through visualization and abstraction. Furthermore, the evaluation should focus on students' skills in dealing with concepts like equality, variables and function, as well as structures in the problems. Finally, the assessment should probe their ability to identify patterns and, importantly, to generalize from observed examples to formulate broader rules or principles. These interconnected dimensions provide a comprehensive view of how interactive tasks can foster and reveal students' computational thinking abilities.

2. Interactive Tasks

In today's skills-based world, the promotion of digital tools for teaching and learning has become increasingly important. The substantial support provided by technology-assisted approaches to education has had a significant impact on educational outcomes. These solutions also provide interaction that is crucial in the acquisition of critical skills, as they enable the transformation of learners' cognitive structures and facilitate effective learning (Johnson *et al.*, 2014; Moore, 1989). Since interaction emerged as a key concept to the cultivation of valuable understanding and practicing in learning contexts, technology-assisted solutions are used to help enhance interaction in educational settings through a wide range of means and methods. As such, computer games and digital simulations are utilized to teach essential skills such as CT (Basawapatna *et al.*, 2011; 2014) with context-appropriate elements of interaction.

Gaining importance in recent years, the literature illustrates a multitude of works that have addressed interactivity in teaching and learning processes, and the utilization of Bebras tasks to impact upon learners' CT skills. For example, Lutz *et al.* (2018) used Bebras tasks to promote students' CT skills in programming training, and stated that a positive relation exists between CT and task completion. Similarly, Chiazzese *et al.* (2018) performed project-based robotics training with the help of Bebras tasks to improve learners' CT skills, and revealed that a positive effect was seen in supporting learners' CT skills. These examples provide insight into how CT skills can be promoted and supported by using Bebras task-oriented interactive products, and how inspiration can be drawn from such attempts to enhance learners' CT skills through effective design with the use of multimedia design principles.

Interactive tasks employ a variety of interaction types to engage learners. 'Click-on-object' interactions allow users to manipulate the state of elements, such as changes in color, shape, or orientation, often revealing underlying concepts or triggering events. 'Drag and drop' functionalities enable users to physically manipulate digital objects, facilitating tasks like categorization, sequencing, or spatial reasoning. Tasks that involve 'Writing text or integers' provide opportunities for students to input answers, define variables, or express their understanding in a textual or numerical format. Finally, 'Click & draw' interactions, such as creating arrows or freehand markings, can support learners in annotating diagrams, illustrating relationships, or visualizing their thinking directly on the interface. These diverse interactivity types offer different affordances for engaging with the learning content.

Incorporating CTML principles into the design of instructional materials has been recommended to enhance learners' achievement, and also to decrease their cognitive load. Various investigations in the existing literature have examined the effectiveness of CTML principles (Basawapatna *et al.*, 2013; Schnotz & Bannert, 2003; Selby, 2015; Torcasio & Sweller, 2010) in promoting CT whereas some studies on CT have identified significant gaps. For example, Tang *et al.* (2020) conducted a systematic review which revealed that CT assessments heavily prioritize programming skills. The researchers also proposed that additional assessments, particularly those focused on quality, are greatly needed in order to achieve better results. Similarly, Hsu *et al.* (2018) reported that CT is primarily used in activities based on computer science. Given that cognitive abilities vary among learners of different ages, it logically sounds that the most appropriate methods and ways should be adopted to promote CT skills, and that this may involve the use of varied approaches so as to effectively foster CT skills at different stages of development.

3. Cognitive Theory of Multimedia Learning

Richard Mayer's cognitive theory of multimedia learning centers on the idea that our working memory has a limited capacity, which can easily be overwhelmed by too much simultaneous information. Mayer proposes that learning is an active process where we build our own understanding from what we are presented with. He also suggests that using both visuals and audio in learning materials can improve understanding by engaging multiple senses and linking different pieces of information. Rooted in cognitive psychology, Mayer's theory aims to optimize multimedia design to match how our minds process information. A key aspect is the **limited capacity of working memory**, meaning instructional materials should be well-structured to avoid overload. Furthermore, Mayer emphasizes **active learning**, where learners actively select, organize, and integrate information, and his principles guide the creation of materials that support these processes for better learning.

Mayer's (2009) cognitive theory of multimedia learning is based on cognitive load theory, which states that our working memory has a limited capacity for processing information at once. Mayer's theory suggests that the information we encounter during learning leads to three kinds of cognitive processing: selective processing, where learners focus on only one part of the information, typically when it's simple; coherent processing, where learners connect new information to what they already know, leading to deeper understanding; and generative processing, where learners actively engage with the material to create new mental representations, which is considered the most effective for learning.

Mayer's theory proposes that multimedia presentations can be structured to encourage these various types of cognitive processing, ultimately leading to improved learning results. For instance, when multimedia is designed to promote generative processing, learners are more likely to remember and use the information in practical contexts.

Extraneous load, or wasted mental effort, arises from non-essential elements that do not aid learning. To reduce this, instructors should stick to the core content and avoid distractions like unnecessary animations or irrelevant details.

Intrinsic load, or the essential mental effort of processing the material itself, depends on its complexity. Instructors can manage this by breaking down content into smaller parts and explaining technical terms beforehand.

Germane load, or the effort learners put into truly understanding the material, is heavily influenced by their motivation. Instructors can boost this by providing learning support and pacing the content well.

Essentially, cognitive load theory expands on the idea of our limited processing capacity. It suggests that to maximize learning and memory, instructors should create multimedia that appropriately manage intrinsic load, optimize germane load, and minimize extraneous load. Consequently, Mayer's principles for effective multimedia design can also be understood as practical strategies for managing cognitive load.

Briefly, the cognitive theory of multimedia learning posits that our minds have separate visual and auditory channels with limited processing power, and that learning is an active process. Therefore, those creating multimedia should design their presentations to carefully manage the demands on these cognitive resources. Mayer views multimedia as tools that help learners build their own understanding, not just as ways to transmit information.

In order to promote effective learning, interactive learning environments that incorporate information and communication technologies are being developed in response to the rapid evolution seen in the use of digital technologies (Liu & Szabo, 2009). Owing to the fact that interaction within learning environments is often facilitated through the use of multimedia elements, Mayer (2013) developed the Cognitive Theory of Multimedia Learning (CTML) to provide a theoretical foundation for the development of multimedia learning environments. Since then, CTML has been identified as a critical theory for instructional technology designers, as it aims to facilitate efficient learning for learners (Cavanagh & Kiersch, 2022).

4. Principles of Multimedia Learning

Drawing on his theories of learning, Richard Mayer outlined twelve principles to guide the creation of effective multimedia learning tools. These guidelines, listed below, aim to help designers produce engaging materials that lead to better understanding and memory.

1. **Multimedia Principle:** Combining words and pictures is more effective for learning than using words alone.
2. **Modality Principle:** Presenting related information visually and audibly is better than using just one of these methods.
3. **Redundancy Principle:** Avoid presenting the same information both as on-screen text and as spoken narration.
4. **Coherence Principle:** Learning is improved by excluding any unnecessary content.
5. **Signaling Principle:** Using cues to highlight important information and the structure of the material enhances learning.
6. **Spatial Contiguity Principle:** Placing related text and visuals close together improves understanding.
7. **Temporal Contiguity Principle:** Presenting spoken words and corresponding graphics simultaneously is more effective.
8. **Segmenting Principle:** Breaking down lessons into smaller, manageable parts helps learners.
9. **Pre-training Principle:** Providing necessary background information before the lesson improves learning.
10. **Image Principle:** Use relevant graphics that help explain the content and support learning objectives.
11. **Personalization Principle:** Avoid formal language and instead use a conversational tone to engage learners.
12. **Voice Principle:** A friendly human voice is better for narration than a computer-generated one.

Ultimately, Mayer's principles offer practical advice for developing effective multimedia learning experiences. By applying these guidelines, creators can design materials that actively involve learners and lead to more profound understanding and better retention of the information.

Among these principles, seven of them, namely coherence, signaling, spatial contiguity, temporal contiguity, segmenting, pre-training, and image principles, which are applicable for text and visuals as well as use of interactivity, are further investigated according to their potential for minimizing extraneous, intrinsic and germane load.

4.1. *Principles That Minimize Extraneous Load*

4.1.1. *The Coherence Principle*

According to the Coherence Principle, people learn better when multimedia messages exclude extraneous material. This means instructors should avoid adding information that will not be tested, is just for show, or distracts from the learning goals. Mayer also points out the danger of "seductive details" – engaging but irrelevant content that can be better remembered than the main points, thus interfering with learners' construction of understanding. To adhere to this, multimedia should only contain learning-relevant graphics, text, and narration, should not include background music, and should use simple visuals.

In the 'Writing text or integers' type interactive task presented in Fig. 1, the use of several simple visuals aims to just improve learning, in other words, students can understand the change in the pattern by just observing relevant graphics.

4.1.2. *The Signaling Principle*

According to the Signaling Principle, adding cues that emphasize the organization of key material helps people learn better. When multiple elements are visible, learners benefit from knowing what to focus on, their current location in the presentation, and how the information fits together to build their mental models. Thus, instructors should use signals to draw attention to important content, but Mayer cautions against

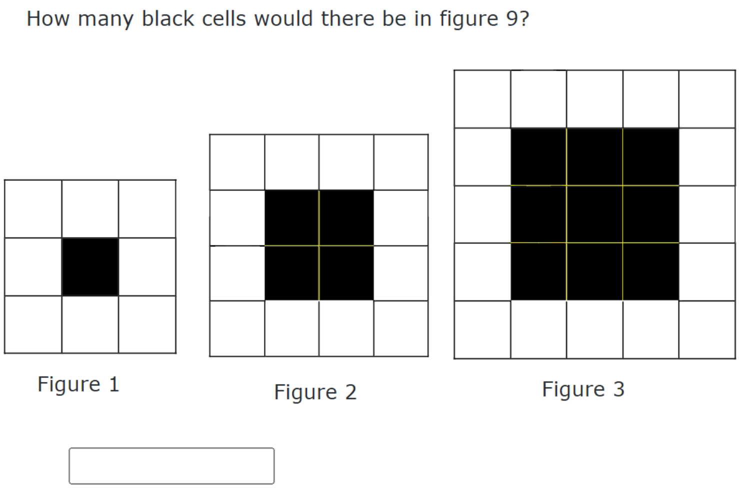

Fig. 1. Example of an interactive task: Writing text or entering integers.

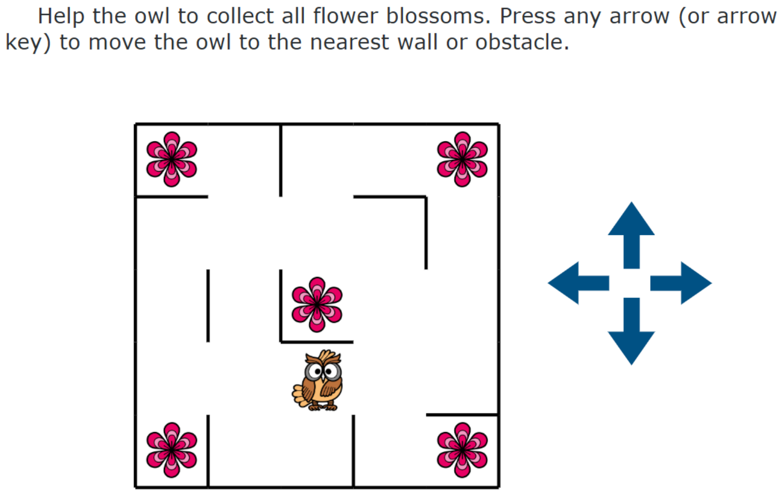

Fig. 2. Example of an interactive task: Click-on-object.

overuse. To apply this principle, use tools for highlighting for emphasis, and provide an advanced organizer that outlines the presentation's structure, referring back to it as you progress.

For example, in the 'Click-on-object' type interactive task seen in Fig. 2, arrows are used for moving the bird to the target. Hence, arrows are the signals in this question which provides interactivity and step by step trial.

4.1.4. *The Spatial Contiguity Principle*

The Spatial Contiguity Principle suggests that learners understand better when related text and visuals are placed close together on the screen or page. This intuitively means keeping labels and captions near the graphics they describe. Doing so reduces the mental effort learners need to connect the text and images, allowing them to focus on understanding and integrating the information instead of scanning the screen to make those links. To apply this, place text near its corresponding graphics, provide feedback close to related questions or answers, present instructions on the same screen as the activity, and have learners read any text before an animation begins.

As it is seen in the 'Writing text or integers' type of interactive question in Fig. 3, although there are too many shapes and words which could lead to a potential cognitive load, combination of verbal and visual elements closer to each other make it easy to understand the question.

4.1.5. *The Temporal Contiguity Principle*

The Temporal Contiguity Principle states that learning is more effective when related words (narration) and pictures (animation) are presented at the same time rather than one after the other. To maximize learning, narration should be synchronized with the

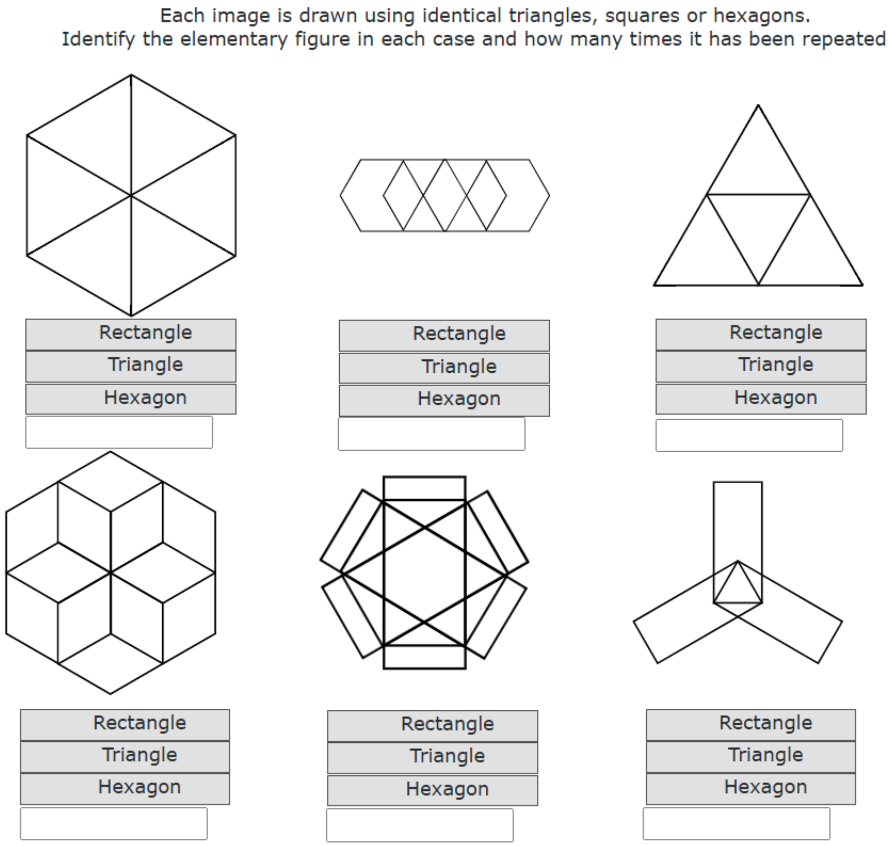

Fig. 3. Example of an interactive task: Writing text (several times).

graphics, rather than having students read an explanation and then see the visuals separately. To apply this, ensure that narration is timed to coincide with the corresponding animations.

For example, in the 'Drag and drop' type interactive task seen in Fig. 4, having all text and graphics altogether makes it easy to understand the problem, and through interactivity students can try and learn even if they make mistakes.

4.2. *Principles That Manage Intrinsic Load*

4.2.1. *The Segmenting Principle*

According to the Segmenting Principle, people learn better when they can proceed through a multimedia message at their own pace, rather than having it presented continuously. Mayer's research with asynchronous lessons on processes showed that allowing students to control the speed improved their recall and transfer abilities. Therefore,

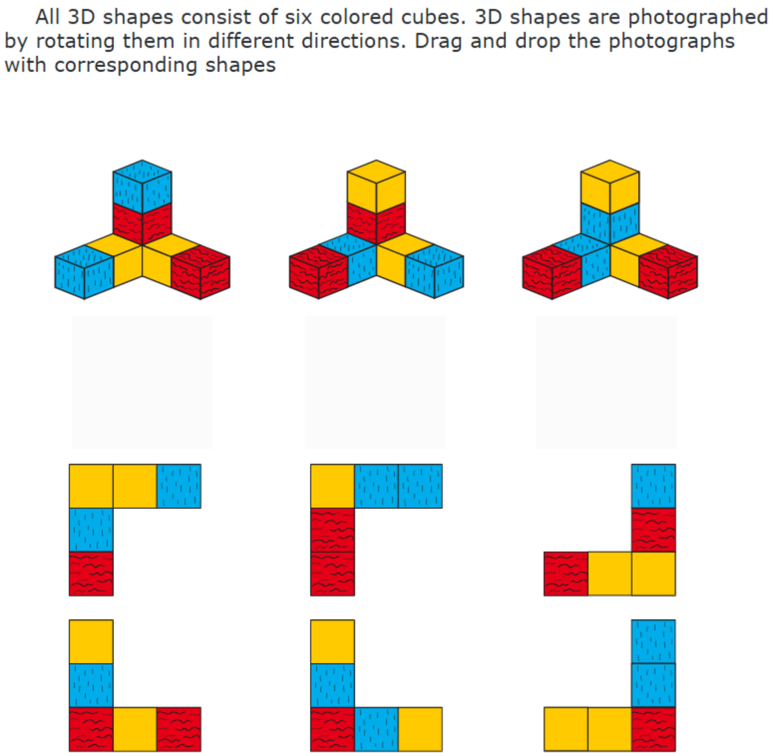

Fig. 4. Example of an interactive task: Drag and drop.

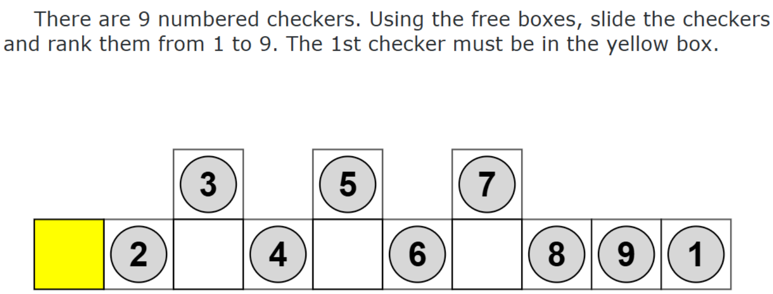

Fig. 5. Example of an interactive task: Drag and drop.

this principle advises giving users control over the lesson's pace (like speed controls or "next" buttons) and breaking down extensive content into smaller segments to allow for sufficient processing at each step.

In the 'Drag and drop' type interactive task seen in Fig. 5, the users can drag numbers and drop empty places having the control over the sorting process, so they can observe each step through interaction, which allows them to work at their own pace.

4.2.2. *The Pre-Training Principle*

The Pre-training Principle suggests that learners understand more deeply when they are familiar with the names and features of the main ideas before the lesson. Because managing the inherent complexity of information can easily overwhelm beginners, instructors should introduce key terms and concepts before explaining processes. Without this pre-training, students might struggle to learn the components of a process while simultaneously trying to understand the process itself, hindering their learning. Essentially, pre-training scaffolds learning by ensuring students have the necessary background knowledge before starting a multimedia lesson.

For example, in the ‘Writing text or integers’ type of interactive task seen in Fig. 6, the students need some pre-training in order to be able to solve the task. Hence, the

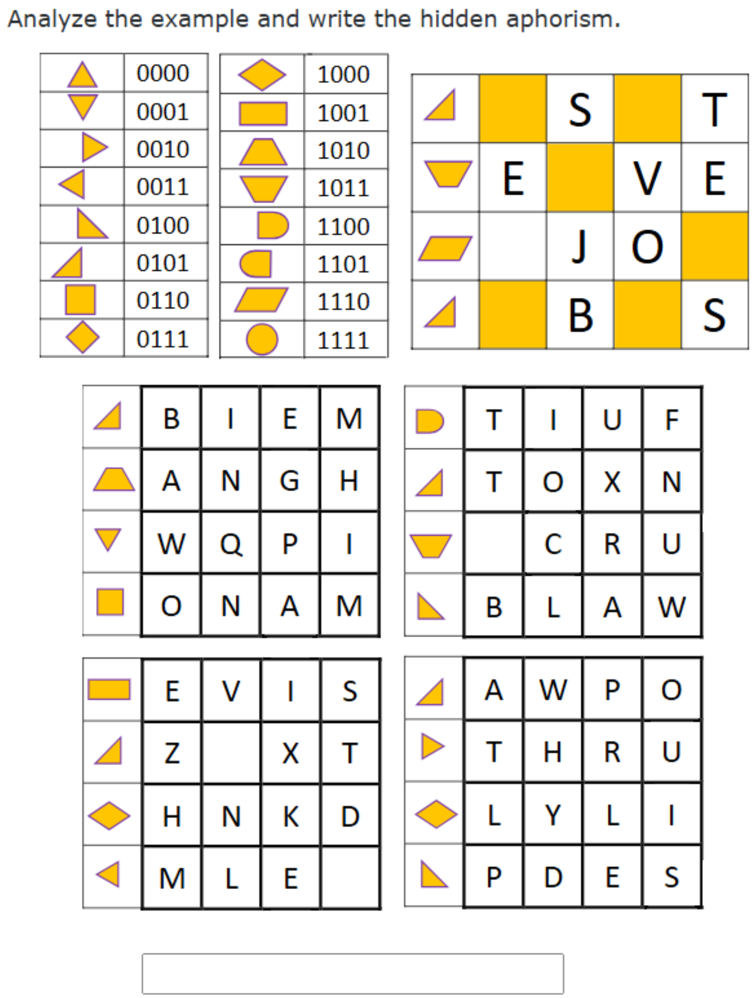

Fig. 6. Example of an interactive task: Writing text or integers.

question provides some clues prior to asking the question. This is where students have to understand the codes related to shapes, so they can apply this information to solve the actual problem.

4.3. *Principle That Optimize Germane Load*

4.3.1. *The Image Principle*

The Image Principle encourages the use of diagrams, animations, or other visual aids that directly relate to the topic being discussed. Using visuals, symbols and images while aligning text closely with these visual cues make information easy to follow or supports easy understanding of concepts and processes.

In the ‘Drag and drop’ type interactive task seen in Fig. 7, the text explanations appear before and after the visual in order to improve the effect of the visual besides text, where use of images support easy understanding of the explanations provided as text.

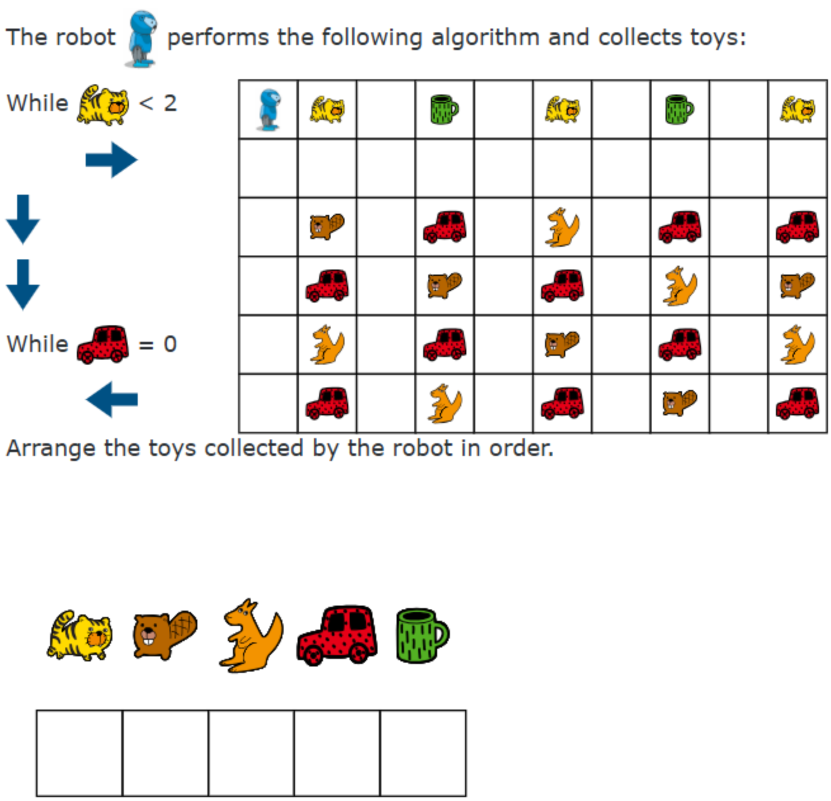

Fig. 7. Example of an interactive task: Drag and drop.

4.4. *Stating the Gap in the Literature*

Research consistently highlights the significant potential of using digital interactive tasks in mathematics education to support thinking processes and foster deeper learning (Mierluş-Mazilu & Yilmaz, 2023; Drijvers & Sinclair, 2024). These tasks, leveraging elements like click-on interactions, drag-and-drop, text input, and drawing tools, can engage students in ways that traditional methods often cannot.

Interactive tasks, especially those incorporating game-based learning or real-world applications, can significantly increase student engagement and motivation in mathematics (Wang, Chang, Hwang, & Chen, 2018; Hwa, 2018; Moon & Ke, 2020). The dynamic and often playful nature of these tasks can also make learning more enjoyable and less intimidating, fostering a more positive attitude towards math (Applebaum, 2025).

Interactivity allows students to visualize and manipulate abstract mathematical concepts, leading to a deeper and more intuitive understanding (Ziatdinov & Valles Jr, 2022). Tasks that require active participation and experimentation help students break down complex ideas and build stronger cognitive connections (Boaler, 2022).

Interactive tasks often require students to actively solve problems and think critically, contributing to the development of these essential skills (Blyznyuk & Kachak, 2024). Studies have shown the positive impact of interactive math apps on early math learning gains, including basic facts, concepts, and higher-level reasoning (Bang, Li & Flynn, 2023; Clements, Lizcano & Sarama, 2023). Besides, digital platforms with features like dynamic representations, simulations, and virtual manipulatives help students engage with math in more meaningful ways (Cirneanu & Moldoveanu, 2024; Bush, 2021).

In conclusion, research strongly supports the use of digital interactive tasks in math teaching as a way to enhance engagement, understanding, and skill development. However, the effectiveness hinges on thoughtful design, appropriate pedagogical integration, and equitable access for all learners. Hence, while the potential is high, the design of effective interactive tasks is crucial to maximize their benefits, since simply digitizing traditional exercises may not yield the desired outcomes.

5. Research Methodology

Based on the literature review and theoretical basis provided, the purpose of this article is to analyze interactive tasks based on the computational and algebraic thinking they promote, the nature of their interactivity, and their adherence to established multimedia principles. To address this issue, we tried to answer the following research questions:

1. What are the typical patterns of student engagement (types of interaction, time spent) within the online learning environment?
2. How does the average time students spend on a task vary across different types of interactive tasks?

3. How frequently are various multimedia design principles (e.g., contiguity, modality, coherence, redundancy) applied across the learning tasks?
4. Is there a statistically significant correlation between the extent to which multimedia design principles are applied in a task and the average scores achieved by students on that task?

By addressing these research questions, the study will provide a comprehensive analysis of the multimedia design effectiveness of the interactive mathematics questions for students. The findings will not only inform the refinement of the platform but also contribute to our understanding of how interactive design and multimedia principles can be optimally applied in educational contexts to foster critical thinking skills.

Hence, this research study is based on quantitative data analysis where descriptive analysis as well as correlational analysis were used.

5.1. *Working Group*

Data from a total of 63 students (Grades 1–2) were used in this study (Table 1). However, some of them did not provide answers to some questions. So, the total number of students answering each question shows variety for each group and task.

5.2. *Interactive Tasks*

The interactive tasks (which are called as COMATH items in the context of the project) used within this research are developed in the scope of CT&MathABLE project (2025) which focuses on benchmarking Computational and Algebraic thinking skills in school systems in the project partner countries. The tasks are provided through a digital online learning platform, ViLLe, which focuses on learning analytics.

Interactive tasks in the Computational Thinking (CT) Dimension of the scale are derived from items developed for the 2022 International Bebras Challenge (Dagienė and Stupurienė, 2016). Algebraic Thinking (AT) items were developed at University of Turku by staff in the Turku Research Centre for Learning Analytics during Autumn of 2023 and Spring of 2024.

Table 1

Demographic Information about Working Group

Grades	Number of Participants	Female	Male
Grades 1–2	63	27	36
Grades 3–4	57	24	33
Grades 5–6	59	26	33
Grades 7–8	28	19	9
Total	**207**	**96**	**111**

A total of 207 students participated in the study; however, the analysis focused on Grade 1 and 2 students, as they represented the largest subgroup and offered the most suitable data for the research objectives.

Interactive tasks for this research study are provided and accessed through ViLLE Platform. ViLLE is a collaborative learning platform[1] developed by the Centre of Learning Analytics of the University of Turku. It offers students and teachers detailed information regarding their learning process in the form of immediate feedback and learning analytics. Teachers can create exercises for their personal use but they can also utilize materials made by others. Most exercises are automatically assessed which allows teachers to spend more of their time supporting students.

In response to the significant findings reported in the literature and Mayer's (2017) call for future research on the use of educational multimedia designed in accordance with CTML principles in educational contexts, the current study explores the integration of these principles in interactive tasks. ViLLE system is not supporting audio and video content, so this research study will focus on the principles which are applicable for text and visuals. The interactive tasks will be evaluated using seven of the multimedia design principles considered appropriate to the characteristics of interactive tasks, which are such as the use of coherence, signaling, spatial contiguity, temporal contiguity, segmenting, pre-training, and multimedia principles.

5.3. *Data Collection*

Data for this study were collected through the implementation of interactive tasks using the ViLLE system. From the system logs, we extracted several key variables: "scores," representing the points students earned for each task; "submissions," indicating the timestamp when a student clicked "Submit" and received immediate feedback; and "time on task," reflecting the total duration a student spent completing each task. Additionally, the dataset includes anonymized student identifiers and gender information. Thus, all data were gathered online via the ViLLE platform to analyze students' performance.

5.4. *Data Analysis*

The data analysis focused on understanding student interaction types, time and performance based on descriptive statistics. The findings can inform improvements in interactive task design and multimedia principles.

[1] `https://en.learninganalytics.fi/ville`

6. Findings

This section presents the results of the study, which aimed to assess interactive tasks in relation to computational and algebraic thinking processes, interactivity types, and the application of multimedia design principles. A combination of descriptive and inferential statistical analyses was conducted to examine patterns in student engagement, task performance, and the instructional quality of the tasks through multimedia design.

The dataset comprises interaction data from 18 tasks completed by students in Grades 1 and 2. Key variables analyzed include the number of students per task, time spent on tasks, average scores, number of submissions, and the frequency and type of multimedia principles applied. Additionally, the study explores the potential relationship between multimedia principles and student performance using non-parametric statistical methods due to the non-normal distribution of score data.

As aligned with the research questions, the results are structured into four main areas: (1) descriptive patterns of student engagement and performance, (2) time on task by interactivity type, (3) frequency and distribution of multimedia design principles across tasks, and (4) correlation between the application of these principles and students' average scores. These findings offer insight into how interactive design and multimedia application may influence students' learning behaviors and outcomes in digital environments.

Descriptive and correlation analyses of the data are presented in Table 2.

The dataset is composed of performance and engagement metrics across 18 tasks completed by students. Below is a summary and interpretation of the key variables:

On average, each task was completed by approximately 32 students. The number of students per task varied, ranging from a minimum of 12 to a maximum of 40. This indicates that while most tasks had similar participation levels, a few were completed by significantly fewer or more students, possibly due to differences in group size or task allocation.

A. Time

In terms of time on task, on average, students spent about 172 seconds (around 2.9 minutes) on each task (Table 3). Some tasks took as little as 48 seconds, while others took

Table 2

Descriptive Results for Grades 1–2

	Mean	Min	Max	Std. Dev.
Time on Task	171.8 s	48.4	502.1	112.9
Time Std Dev	142.8	25.5	411.2	110.8
Average Score	5.24	0.00	10.0	3.24
Score Std Dev	3.32	0.00	4.92	1.36
No. of Submissions	1.69	1.00	2.93	0.52
Submission Std Dev	1.04	0.00	2.30	0.65

Table 3
The average time spent on each interactivity type

Task	Time on task	Interactivity
1	97	Drag and drop
2	93	Drag and drop
3	48	Drag and drop
4	90	Drag and drop
5	197	Write text, integer
6	115	Write text, integer
7	198	Click
8	189	Write text, integer
9	79	Click
10	157	Write text, integer
11	113	Click
12	502	Drag and drop
13	131	Click
14	140	Click
15	119	Write text, integer
16	266	Drag and drop
17	182	Click
18	377	Click

more than 8 minutes. This big difference shows that some tasks were much harder or more detailed than others. While a few tasks were quick and easy to finish, others took a lot more time – probably because they were more difficult, had more content, or needed more interaction. The high variation (112.9 seconds) also shows that the time students spent on each task was quite different from one task to another.

B. Interactivity type

Tasks that involved Click on object and Drag and Drop interactions took the longest average time to complete, suggesting these may require more exploration or user engagement. Write-type tasks, where students input text or numbers, took moderately less time, possibly due to more direct response formats.

C. Performance (Score)

Score variability is relatively high, implying that some students performed very well while others struggled, possibly due to differences in multimedia principles. Number of Submissions as an indicator of performance shows that on average, students submitted each task about 1.7 times. The number of submissions ranged from 1 to almost 3 times.

This shows that many students submitted the same task more than once. This might mean they had a chance to revise their work, made mistakes on the first try, or wanted to improve their scores by trying again. In line with this, the standard deviation for the number of submissions was 1.04, which indicates there was a noticeable difference among students in how often they resubmitted tasks. Some students submitted only once, while others submitted multiple times. The variation in submission frequency further supports the likelihood of repeated attempts or iterative learning processes for certain tasks.

Multimedia principles

An analysis of multimedia principle usage across the interactive tasks is shown in Table 4.

The result of the analysis reveals that the *Temporal Contiguity Principle* was the most frequently applied, being present in 100% of the tasks. A number of other principles were also widely implemented. Specifically, the *Redundancy Principle, the Spatial Contiguity Principle, and the Image Principle* were each applied in 94.4% of the tasks, indicating strong alignment with best practices for presenting visual and verbal information effectively.

In terms of moderate usage, both the *Segmenting Principle* and the *Pre-training Principle* appeared in 83.3% of the tasks. These were followed by the *Coherence Principle*, which was used in 77.8% of tasks, and the Signaling Principle, present in 72.2%.

Regarding multimedia principles and the average scores, the data do not meet the requirements for a parametric test. A Shapiro-Wilk test was conducted to assess the normality of the score data. The results indicated a deviation from normality, $W = 0.89$, $p = .037$. Therefore, the assumption of normality was violated, and non-parametric tests were used in subsequent analyses. Since the p-value is less than 0.05, the null hypothesis of the Shapiro-Wilk test was rejected. This means that the score data is not normally distributed.

The correlational analysis was run based on each principle. The result of the analysis is shown in Table 5.

Table 4
Frequencies of Principles within Questions

Principle	f	%
Temporal Contiguity	18	100
Redundancy Principle	17	94,44
Spatial Contiguity Principle	17	94,44
Image principle	17	94,44
Segmenting Principle	15	83,33
Pre-training Principle	15	83,33
Coherence Principle	14	77,78
Signaling Principle	13	72,22

Table 5
Correlation Between Multimedia Principles and Student Scores

Principle	Point-Biserial r	p-value
Redundancy Principle	0.19	0.44
Coherence Principle	0.59	0.01
Signaling Principle	0.50	0.03
Spatial Contiguity	0.19	0.44
Segmenting Principle	0.42	0.08
Pre-training Principle	0.52	0.02
Image Principle	0.26	0.30

A non-parametric point-biserial correlation, a specialized form of Pearson's correlation for measuring the relationship between a continuous variable (average score) and binary variables (multimedia principles, coded as 0/1) was used to analyze the data. Temporal Contiguity Principle is excluded because all values are constant (all 1s) and this makes correlation undefined. The analysis revealed statistically significant positive correlations for the Coherence Principle ($r = 0.59$, $p = 0.01$), Signalling Principle ($r = 0.50$, $p = 0.03$), and Pre-training Principle ($r = 0.52$, $p = 0.02$), suggesting that the presence of these principles is associated with higher average scores. Other principles, including Redundancy, Spatial Contiguity, and Segmenting, did not show significant relationships with the average score ($p > 0.05$).

7. Conclusion

This study examined the effectiveness of interactive tasks in promoting computational and algebraic thinking skills among primary and lower secondary students, with a focus on interactivity types and the application of multimedia design principles. The analysis, based on data collected from 63 students across multiple grade levels, provided insight into learner performance in terms of average scores, time on task, and number of submissions, as well as the instructional quality of task design.

Descriptive results revealed that the majority of tasks were completed within approximately three minutes, though there was considerable variation in completion time, suggesting differences in task complexity and cognitive demand. Tasks involving Click-on-object and Drag-and-drop interactions took longer to complete, indicating that these formats may encourage exploration and deeper engagement. Conversely, Write-type tasks resulted in shorter engagement time, possibly due to their more straightforward input structure. The number of submissions also indicated active student engagement, with several students revisiting tasks – suggesting that the platform effectively supported iterative learning.

From a multimedia design perspective, the most frequently applied principles were Temporal Contiguity, Spatial Contiguity, Redundancy, and the Image Principle, each appearing in over 94% of tasks. These align well with Mayer's Cognitive Theory of

Multimedia Learning, which emphasizes minimizing extraneous load and promoting meaningful learning through the integrated presentation of verbal and visual content.

The results demonstrate positive correlations for the Coherence, Signaling and Pre-training Principle with higher average scores. These results reinforce prior literature suggesting that effective multimedia design can positively influence learning outcomes when principles are applied deliberately (Dubois & Vial, 2001; Mayer, 2017).

Importantly, the findings also reflect on the alignment of interactivity types and multimedia principles. Tasks that embedded multimedia design more consistently tended to correlate with higher scores and increased engagement, supporting the notion that cognitive load can be strategically managed through careful instructional design (Schnotz & Bannert, 2003).

In sum, this study supports existing research that emphasizes the pedagogical value of interactive, well-structured multimedia tasks in fostering computational and algebraic thinking. These findings can inform educators and designers in developing more adaptive and cognitively balanced learning environments that enhance both engagement and achievement. Future research may consider longitudinal studies and qualitative feedback to explore how learners perceive and respond to these design elements over time.

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