Computational Thinking and Mathematical Problem Solving, an Analytics Based Learning Environment

White Paper #5: Interactive Tasks in ViLLE to Support Development of CT and AT Skills

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Executive Summary

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).

The CT&MathABLE project provides technological and pedagogical tools to support effective learning in Computational Thinking (CT) and Algebraic Thinking (AT). A tool was developed in which interactive tasks and a set of interactive resources could be created for learners. This outcome empowers educators to incorporate CT and AT into classroom practices.

A set of 100 interactive tasks was created and piloted in authentic classroom contexts with students between the ages of 9 and 14. These pilots were designed to ensure that the tasks were engaging, usable, and pedagogically sound. After the piloting phase, the tasks were integrated into a learning ecosystem that included analytics, enabling personalized learning paths, real-time feedback, and alignment with the project's assessment instruments. This approach supports both formative and summative assessment. Research into interaction design further refined the user experience, optimizing both the process, and the interface, in order to maximize learner engagement.

1 Introduction

Interactive tasks use a range of interaction types to actively engage learners:

- Click-on-object interactions let users change the state of elements—such as color, shape, or orientation—to reveal concepts or trigger events.
- Drag-and-drop features allow users to move digital objects, supporting activities like categorization, sequencing, or spatial reasoning.
- Text or number input tasks invite learners to write responses, define variables, or demonstrate understanding in written or numerical form.
- Click-and-draw interactions, such as drawing arrows or freehand annotations, help learners visualize ideas, highlight relationships, or mark diagrams directly on the interface.

These different types of interaction offer a variety of ways for learners to engage with the content in a meaningful way. Enhancing meaningful learning outcomes and reducing cognitive load is achieved by applying the Cognitive Theory of Multimedia Learning (CTML) principles when designing instructional materials. Research has shown CTML to be effective in promoting computational thinking (CT) [Basawapatna et al.(2017), Schnotz and Bannert(2003), Selby(2015), Torcasio and Sweller(2010)]. However, some studies have identified gaps in CT education. For instance [Tang et al.(2020)] found that CT assessments tend to focus heavily on programming skills, and emphasized the need for more diverse and quality-focused evaluation methods. Similarly, [Hsu et al.(2018)] noted that CT is often taught primarily through computer science activities. Given that cognitive abilities vary between age groups, it is important to adopt developmentally appropriate strategies. A variety of approaches may be necessary to effectively foster CT skills at different stages of learner development.

2 Theoretical underpinnings

Interactive tasks, especially those involving games or real-world contexts, can significantly boost student engagement and motivation in mathematics [Wang et al.(2018), Hwa(2018), Moon and Ke(2020)]. Their playful nature helps make math more approachable and enjoyable, fostering positive attitudes [Applebaum(2025)]. By enabling students to visualize and manipulate abstract concepts, interactivity deepens understanding and supports intuitive learning [Ziatdinov and Valles Jr(2022)]. Active participation encourages experimentation, helping learners break down complex ideas and form stronger cognitive connections (Boaler, 2022). These tasks also promote critical thinking and problem-solving, essential skills in math education [Blyznyuk and Kachak(2024)]. Research also shows that interactive math apps are valuable tools to enhance early learning in basic facts, concepts, and higher-order reasoning [Bang et al.(2023), Clements et al.(2023), Clements et al.(2023)]. Digital platforms with dynamic visuals and virtual features permitting manipulation of key dimensions of a task further enrich engagement [Cirneanu and Moldoveanu(2024), Bush(2021)]. In summary, digital interactive tasks are a powerful tool for improving math learning. However, their success depends on thoughtful design, pedagogical alignment, and equitable access. Simply digitizing traditional exercises is not enough, to be effective interactivity must be intentional and well-integrated into a delivery platform.

Mayer's Mayer(2009), Mayer(2013), Mayer(2017) *Cognitive Theory of Multimedia Learning* builds upon *Cognitive Load Theory*, which asserts that our working memory has a limited capacity for processing information at any given time. Cognitive Theory of Multimedia Learning (CTML) provides a theoretical foundation for the development of multi-media 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 and Kiersch(2022)] and thus is focussed on three core ideas.

- **Selective processing** – Learners focus on specific parts of the information, typically when the material is simple.
- **Coherent processing** – Learners connect new information to prior knowledge, resulting in deeper understanding.

- **Generative processing** – Learners actively engage with the material to create new mental representations. This is considered the most effective form of learning.

The theory also emphasizes that learning is an active process and that our minds use separate visual and auditory channels, each with limited capacity. Therefore, multimedia should be designed to carefully manage these cognitive resources. Mayer views multimedia not just as a means of transmitting information, but as tools that help learners construct their own understanding. CT&MathABLE interactive tasks build on Mayer's theory, supporting these cognitive processes and improving learning outcomes. The multimedia tasks encourage generative processing, learners are, therefore, more likely to retain and apply the information in practical contexts. In our context we used Cognitive Load Theory to analyse three types of mental effort associated with task performance.

- **Extraneous load** – Caused by non-essential elements that distract from learning (e.g., irrelevant animations or details). Instructors should minimize this by focusing on core content.

- **Intrinsic load** – The inherent complexity of the material. This can be managed by breaking content into smaller parts and explaining technical terms in advance.

- **Germane load** – The effort learners invest in understanding and integrating new knowledge. This is influenced by motivation and can be enhanced through supportive teaching and well-paced content.

To optimize learning and memory, instructors should minimize extraneous load, manage intrinsic load appropriately, and maximize germane load. This White Paper explores the task design in relation to these principles, and is organised in relation to the following research questions.

- What are the typical patterns of student engagement (types of interaction, time spent) within the online learning environment?

- How does the average time students spend on a task vary across different types of interactive tasks?

3 Data Collection and Results

Data for this study were collected for a carefully curated series of interactive tasks delivered through the ViLLE learning analytics system. The following variables were extracted from the system logs: 'scores', representing the points students earned for each task; 'submissions', indicating the time stamp when a student clicked 'Submit' and received immediate feedback; and 'time on task', reflecting the total duration a student spent completing each task, together with some anonymised demographic identifiers and gender information. Responses from a total of 63 students (Grades 1–2) were used in this study, though there were varying response rates for the different test items. About half of the pupils registered at least one attempt at each task on average (average 32 responses per task, min 12, max 40). Basic statistical measures applied to the task collection allows us to determine some basic performance measures for the population in relation to the complete task set (See Table 1).

Measure	**Mean**	**Min**	**Max**	**Std. Dev.**
Time on Task (s)	171.8	48.4	502.1	112.9
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 1: Descriptive statistics for Grades 1–2

	Time (seconds)				
Interactivity Type	# tasks	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Click	6	79	377	174.29	97.98
Drag and drop	7	48	502	182.67	173.79
Write text, integer	5	115	197	155.40	38.14

High standard deviation for all types of task indicates that solution time is dependent on the complexity of the task itself, and that substantial variation in complexity is possible using all interaction types. The category of interaction that evidences the lowest standard deviation in solution time is ”write text, integer”, and it appears that this interaction type is characterised by lower complexity and more uniform solution times than more complex forms of interaction such as ”drag and drop” and ”click”.

4 Conclusions

The effectiveness of interactive tasks in promoting computational and algebraic thinking skills among primary and lower secondary students is partially influenced by the type of interactivity used and the application of multimedia design principles. Analysis of data collected from 63 students across multiple grade levels, revealed that the majority of tasks were completed within approximately three minutes, though there was considerable variation in completion time, which we attribute to differences in task complexity and cognitive demand.

Tasks involving Click-on-object and Drag-and-drop interactions took longer to complete, suggesting that these formats allow task designers to explore more complex ideas resulting in deeper learner engagement. Conversely, Write-type tasks resulted in shorter engagement time, possibly due to the more straightforward input structure and limitations on task complexity. Active student engagement is deduced from the fact that many students submitted multiple solution attempts, with several students revisiting tasks – suggesting that the platform effectively sup- ported iterative learning, reflection and revision of solutions.

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