

CMSC 2026 · PADOVA

BRIDGING COMPUTATIONAL THINKING AND MATHEMATICS THROUGH TANGIBLE LEARNING MATERIALS

Valentina Dagienė · Eglė Jasutė · Vaidotas Kinčius · Marika Parviainen

Institute of Educational Sciences, Vilnius University, Vilnius, Lithuania
valentina.dagiene@mif.vu.lt · egle.jasute@fsf.vu.lt · vaidotas.kincius@fsf.vu.lt · marika.parviainen@fsf.vu.lt

A question for the poster session

Can computational reasoning become something a primary-school learner can touch, test, revise, and explain - without turning the physical object into a mere copy of a screen?

Our design aim

Transform the reasoning structure of Bebras-style computational thinking tasks into physical actions that make problem-solving visible while activating primary mathematics.

Key message: the object is not the learning goal; the visible reasoning it supports is.

COMPUTATIONAL THINKING

TANGIBLE LEARNING

CS UNPLUGGED

PRIMARY MATHEMATICS

PROBLEM SOLVING

DigiMaths
4 ALL



Make the thinking observable

When only the final answer is visible, the reasoning path can remain hidden

The Educational Problem

CT involves decomposition, pattern recognition, abstraction and algorithmic thinking. These processes may remain hidden when only the final answer is visible.

Primary mathematics already offers rich structures - number properties, spatial relations, patterns and optimisation - that can carry CT ideas.

The challenge is therefore not to add more devices, but to design tasks in which learners can expose, inspect and revise their reasoning.

HIDDEN REASONING

OBSERVABLE ACTION

TEST + REVISE

EXPLAIN + COMPARE

Why an unplugged / Tangible mode?

CS Unplugged has long been used to communicate computing ideas without depending on computers [1].

Tangible interfaces can support learning through action and social interaction, but their educational value depends on how the interaction is designed [3].

Physical manipulation can externalise decisions so that teachers and peers can discuss how a solution is reached - not only whether it is correct.

From a CT concept to a physical action

The transformation preserves the task's reasoning structure while changing the mode of interaction.

CT CONCEPT

TASK REPRESENTATION

PHYSICAL INTERACTION

TANGIBLE MANIPULATIVE

Learner reasoning

PREDICT

TEST

EXPLAIN

REVISE

Three design criteria

- 1) the learner performs an observable problem-solving action;
- 2) the material supports testing or revising a solution;
- 3) the task links a CT concept with primary mathematics content.

Material	CT structure	Visible physical action	Primary mathematics link
Bebras cards	Sorting, rule following, pattern recognition	Classify, order, follow or justify a rule	PrimaPatterns, number reasoning
Sorting Machine	Conditional reasoning / branching	Route a number through yes/no decisions	Parity, divisibility, number properties
Bee Hive	Constraint satisfaction	Place pieces while satisfying constraints	Geometry, spatial relations
Watering Flowers	Network construction + optimisation	Connect, test and improve a pipe network	Paths, comparison, spatial reasoning
Caesar Cipher	Reversible procedure + cyclic pattern	Rotate mappings; encode and decode	Cycles, position, regular patterns

The prototypes illustrate different CT structures translated into observable physical actions.

CT
Constraint satisfaction and systematic search;
Abstraction: focus on relevant relations, ignore decoration;
Testing: reject placements that violate a rule

MATHEMATICS
Spatial relations and geometry;
Spatial relations and positional patterns;
Reasoning about possible and impossible arrangements



Bee Hive prototype.

Bee Hive: constraints you can move

Object placement represents a constraint problem; every move can be checked against what must remain true.

Task variations that change difficulty

- Increase the number of pieces or simultaneous constraints.
- Remove some information and require deduction before placement.
- Ask whether a solution is unique, or compare two valid arrangements.
- Require an explanation of which constraint ruled out a tempting move.

Teacher mediation moves learners from trial and error to testing, revising, and explaining constraints

- "Where should this piece go first, and why?"
- Ask learners to state which condition each move must satisfy.
- Encourage trying a placement, checking it, and revising if needed.
- "Can the pieces be arranged in another valid way?"
- When a solution fails, ask which two constraints are incompatible.
- Add more cells, more pieces, or extra placement rules.
- Ask learners to justify not only one move, but why the complete configuration works.

CT
Network construction and optimisation;
Testing and revising solutions;
Comparing alternative configurations

MATHEMATICS
Spatial reasoning;
Path and network comparison;
Counting components;
Optimisation criteria



Watering Flowers prototype.

Watering Flowers: from "works" to "works better"

Movable pipes turn a network into an object that can be built, inspected, compared and improved.

Teacher mediation moves learners from "works" to "works better."

- "Which pipe should you place first, and why?"
- Is the task to reach a target, connect as many flowers as possible, or optimise the network using a stated criterion?
- "Both designs work — which one is better, and how can you prove it?"
- Ask learners to identify a pipe that could be removed without breaking the network.
- After a working solution is found, ask learners to improve it with the fewest possible changes.
- Add more flowers, limit the number of pipes, introduce blocked positions, or require learners to justify why no better configuration is possible.

Caesar Cipher + a repeatable classroom cycle

Encoding makes a reversible procedure tangible; teacher mediation turns manipulation into explanation.

Teacher mediation moves learners beyond simply turning the wheel.

- "Where will this letter move if the shift is +3?"
- Give one plaintext-ciphertext pair and ask learners to infer the shift.
- After encoding a word, ask learners to decode it without changing the rule.
- "Is it faster to count each step, follow the alphabet cycle, or identify the shift first?"
- Present an incorrectly encoded word and ask learners to locate and explain the mistake.
- Vary the shift, use wrap-around from Z to A, hide the key, or ask learners to design a coded message for a partner.

CT
Reversible procedure, Information Transformation, cyclic patterns

MATHEMATICS
Regular patterns, position in a cycle;
Modular-style reasoning



Caesar Cipher prototype.

Sorting Machine & Bebras Task Cards

Conditional decisions become a visible route; classification becomes something learners can test and justify.

CT
Conditional reasoning;
Classification;
Rule following and testing decisions.

MATHEMATICS
Number properties;
Parity;
Divisibility.



Sorting Machine prototype.

Possible task progression

- Classify with one rule (for example, even / odd).
- Combine two yes/no rules and predict the final branch before moving the token.
- Test a borderline or counterexample number and revise an incorrect rule.
- Design a rule set that separates a given group of numbers, then explain why it works.

What becomes visible?

The exact decision path, the point at which an error occurs, and the learner's justification for changing a rule.



AGE 6+ 7+ 8+ 9+ 10+ 13+

WHAT THIS POSTER CONTRIBUTES

Design contribution now; classroom evidence next

The current contribution is design-based: it presents a prototype collection and a design framework, rather than evidence of learning effectiveness.

Design outcomes

- A reusable mapping from CT concepts to task representations, physical interactions and mathematics links.
- A prototype set covering branching decisions, spatial constraints, network optimisation and reversible information transformation.
- A reusable task-variation principle: vary numbers, constraints, components or explanation demands while keeping the same manipulative.

Future classroom work

- Further systematic classroom trials with Grade 4 students and teachers.
- Examine learner strategies and solution revisions.
- Analyse explanations, collaboration and teacher adaptations.
- Use the findings to refine task design and implementation guidance.

Iterative design cycle

DESIGN

CLASSROOM USE

OBSERVE REASONING

REFINE DESIGN

Primary references

- [1] Bell, T., Vahresheid, J. (2018). CS Unplugged - How Is It Used, and Does It Work? LNCIS 11011, 497-521. doi:10.1007/978-3-319-98355-4_20.
[2] Dagienė, V., Karpavičiūtė, P., Glanoutsov, N., Engelhardt, K., Malagol, G., Bocconi, S. (2024). Fostering computational thinking in compulsory education in Europe: a multiple case study. Baltic Journal of Modern Computing, 12(2), 189-221. doi:10.22364/bjmc.2024.12.2.05.
[3] Marshall, P. (2007). Do tangible interfaces enhance learning? TEI 2007, 163-170. doi:10.1145/1226969.1227004.
[4] Parviainen, M. (2020). Task Design and Intervention Model for Integrating Computational Thinking into Primary Mathematics. Informatics in Education, 25(2), 111-134. doi:10.15388/infedu.2504.023.

Acknowledgment

Associated with the DigiMaths4All project (No. P-EDU-23-13), co-funded by the European Union under Breakthrough in Educational Research (No. 10-044-P-0001) through the Research Council of Lithuania. This study (No P-EDU-23-13) is co-funded by the European Union (the project "Breakthrough in Educational Research" No 10-044-P-0001) under the 1st April 2025 Agreement with the Research Council of Lithuania and the 15th April Joint Activity Agreement with Vilnius University. Additional funding is provided by the Research Council of Finland (EDUCA Flagship #358924, #358947) and the Ministry of Education and Culture (Doctoral school pilot #VN/3137/2024-OKM-4K).

All photos and illustrations by Eglė Jasutė and Vaidotas Kinčius. © Bebrasplay.com wooden game design.