University of Glasgow

Grounded cognition for conceptual understanding in computing education

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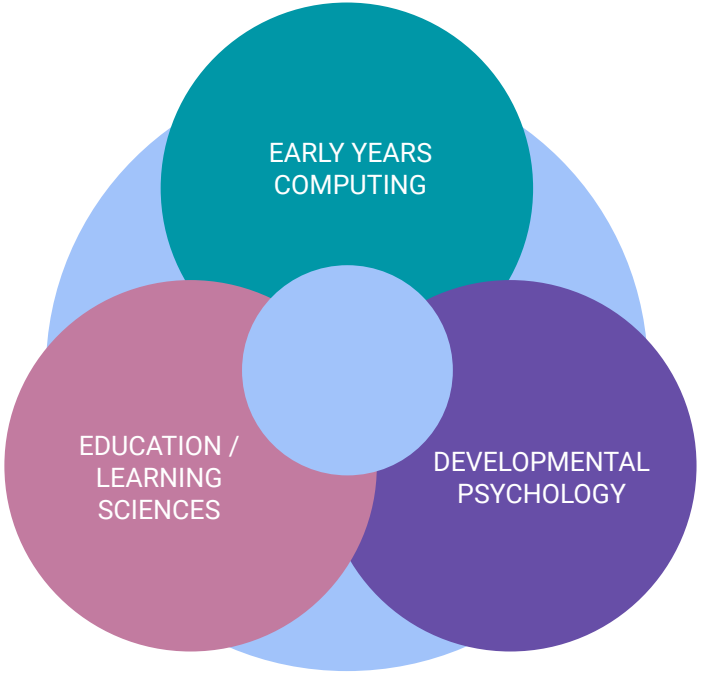
Interdisciplinary research perspective

- Complex subjects require interdisciplinary research



What is grounded cognition?

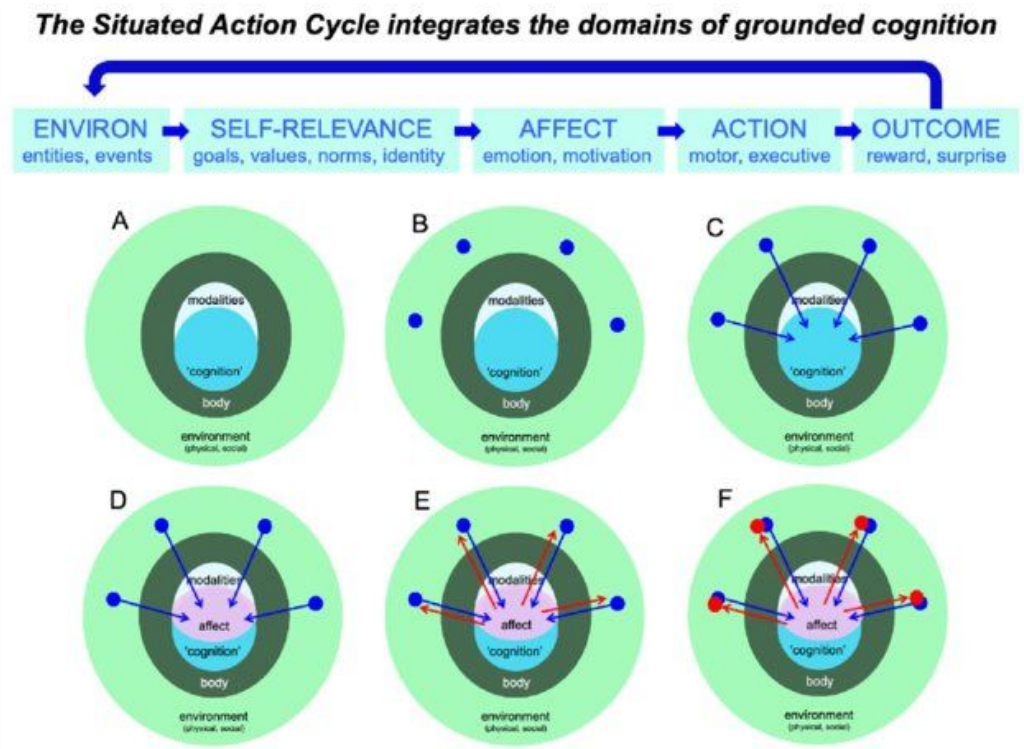
- **Grounded cognition (GC) posits that our thinking is influenced by our physical experiences, and dynamic actions like movement impact our understanding of the world around us**

- **It highlights the role of body, action and simulation to create mental representations of the world around us**

Where does knowledge come from?

What is the nature of knowledge

Grounded and situated cognition



Barsalou, 2020

Cognition is thought of from a **systemic** perspective and in terms of a **situated action cycle**

Different levels in the system include

- classical aspects of cognition (i.e attention, memory, perception)
- Perceptual modalities
- Our body
- Our physical environment

What evidence do we have? -> Gesturing and learning

- Large body of work on the association between gesturing and understanding (Goldin-Meadow and Beilock, 2010)
- Gestures precede words both ontogenetically and phylogenetically (Call & Tomasello, 2007).
- Babies often gesture before they speak (Iverson & Goldin-Meadow, 2005).
- **Action-concept congruency seems to be specifically relevant**

What evidence do we have? -> Conceptual learning

- Abstract learning grounded in embodied metaphors (Lakoff, 2012)
- Embodied mathematics (Lakoff and Nuñez, 2013).
- Action enhances comprehension (Glenberg and Kaschak, 2002).
- **Physical manipulation is important for understanding**

Computing education

- Computing education deals with the introduction of abstract concepts
- Abstraction is a very relevant process in computing that is hard to teach
- Agreement on the value of CS knowledge for children, studies that have shown children can grasp basic CS concepts from the age of 3 (Bers et al., 2020)

Relevance for computing education

- **Growing trend internationally towards the inclusion of computing and computational thinking in compulsory curriculums** (Bocconi et al., 2016; Bocconi et al., 2021)

- **A wide variety of both technological and non-technological tools have been created to introduce children to CS and CT** (Yu & Roque, 2019; Bakala et al., 2021)

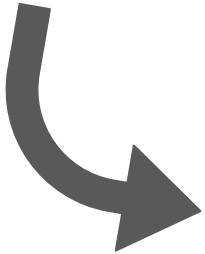
How can we capitalise what we know of child cognitive development to contribute to computing education?

Big question

- **How do we teach young children fairly abstract computing concepts (e.g sequences, repetition, selection)**

Conceptual understanding

- **A student's ability to think about, operate with, explain to others, create analogies and build a mental or physical model of a given concept**



Conceptual understanding as a process of abstraction

Grounded cognition

- **Many activities for young children integrate cognitive and sensory-motor aspects, potentially considered as *grounded activities***

EIFFEL (Enacted Instrumented Formal Framework for Early Learning in Computing) model

This conceptual model was proposed by Kallia and Cutts (2022) based on the premises of grounded cognition.

It organises instruction by prioritising the following:

- **Action concreteness:** according to their level of abstraction, actions are classified as enacted, instrumented or symbolic
- **Action-concept congruency**: defined as the link between the action and the semantic meaning of the learning objective
- **Object concreteness fading**

EIFFEL (Enacted Instrumented Formal Framework for Early Learning in Computing) model

Types of actions in activities:

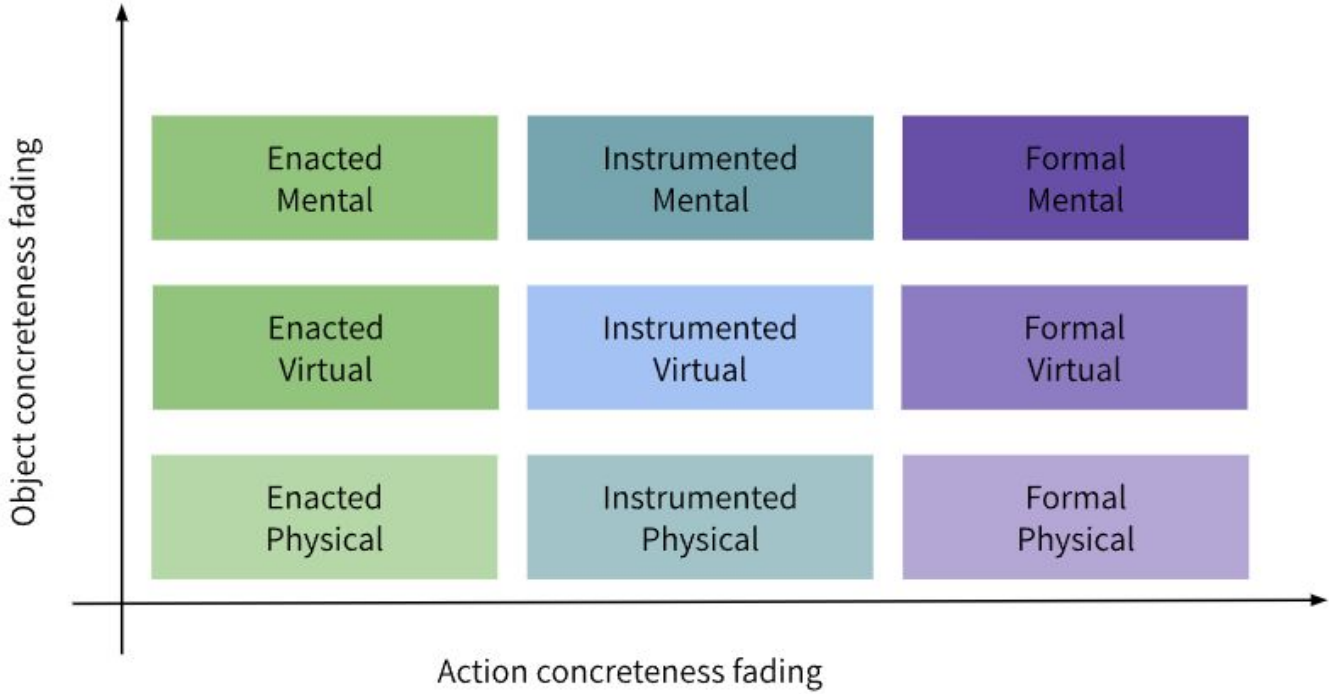
- **Enacted:** Physical actions happening in the physical environment, in which the individual is the actor of the activities
- **Instrumented:** Students perform actions in a virtual environment which involve the manipulation of pictures or symbols but do not require a formal symbolic language (i.e they might use a simplified pictorial placeholder instead of constructing their code)
- **Formal:** Students perform symbolic actions in a virtual environment. They are the authors of their programmes and use a specific syntax to create and modify their programmes

EIFFEL (Enacted Instrumented Formal Framework for Early Learning in Computing) model

Types of objects in activities:

- **Physical:** Tangible 3D objects which individuals are able to manipulate freely
- **Virtual:** Intangible objects set in a computer or tablet screen which individuals manipulate through dragging or tapping with their fingers
- **Mental:** Intangible representations of objects in the physical or virtual world that do not have a 3D or 2D correlate, and in which operations are done through evoking

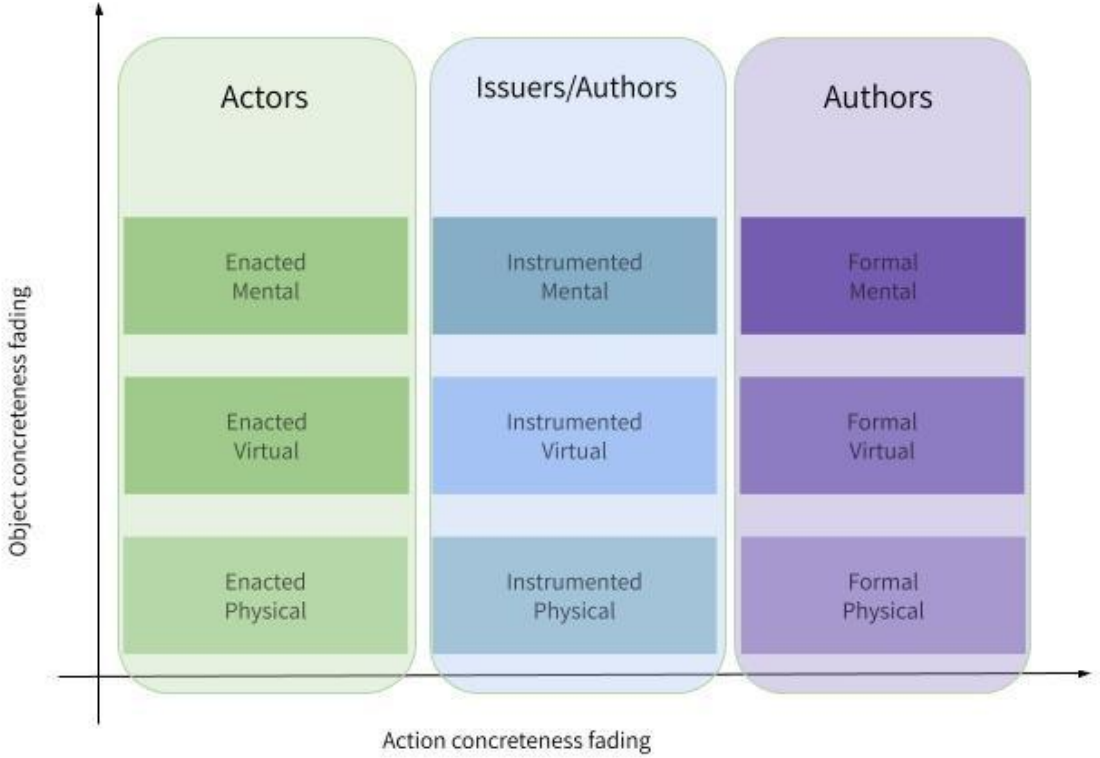
EIFFEL model for early computing



EIFFEL (Enacted Instrumented Formal Framework for Early Learning in Computing) pupil's roles

- **Actor:** Children represent their programmes using themselves as objects
- **Issuer:** Children learn to give commands to a machine and see the output of their command in a physical or virtual output
- **Author:** Children use symbolic language to construct their own code and engage in the planning, testing and evaluation of their programmes

EIFFEL: learners' roles



Can we identify grounded cognition practices in previous research and reported experiences?

- **Review paper (Gerosa, Kallia and Cutts, 2023) we explored physical and action-based reported in the literature for children 4-12**

What were we looking for?

- **Computing activities specifically linked to GC**
- **Computing activities integrating whole-body physical action**
- **Manipulation of concrete, 3D objects**

Search strategy

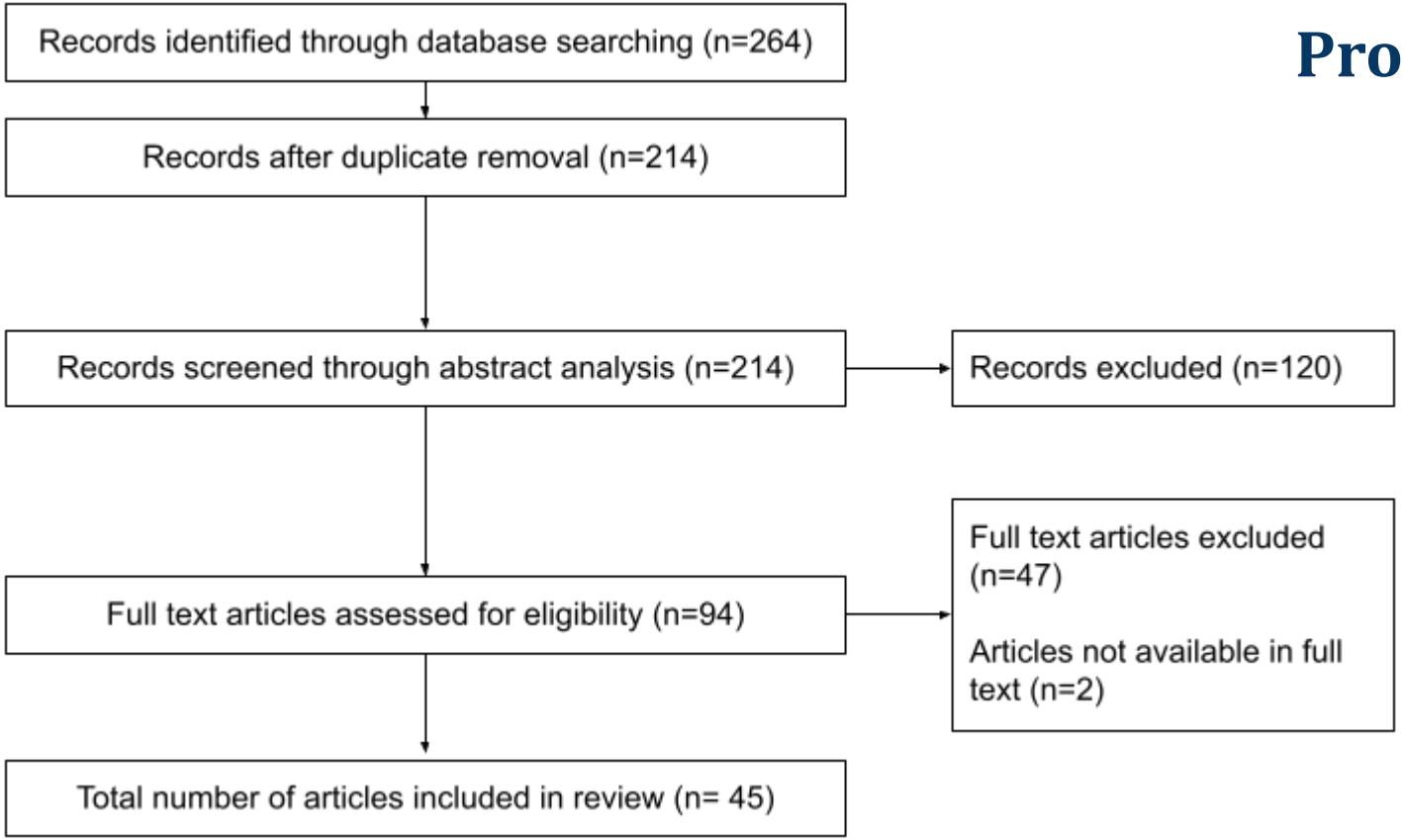
We used four databases for our search, namely ACM digital library, IEEE, ERIC and Scopus.

(1) Participants are children attending early years or primary school (**4 to 12 years of age**)
(2) Participants take part in **computer science or computational thinking** learning activities
(3) **Empirical studies** published in peer-reviewed journals or conferences
(4) Sample is **neurotypical**.
(5) Publication year **between 2006 and 2022**

Research questions

1. **What kind of grounded (i.e. physical and action-based) approaches have been researched in CS education for young learners?**
2. **Which theoretical background informs this research?**
3. **How is grounded cognition reflected in the activity design?**
4. **What were the outcomes (learning, cognitive and motivational) of these approaches?**
5. **Which technological tools were used?**

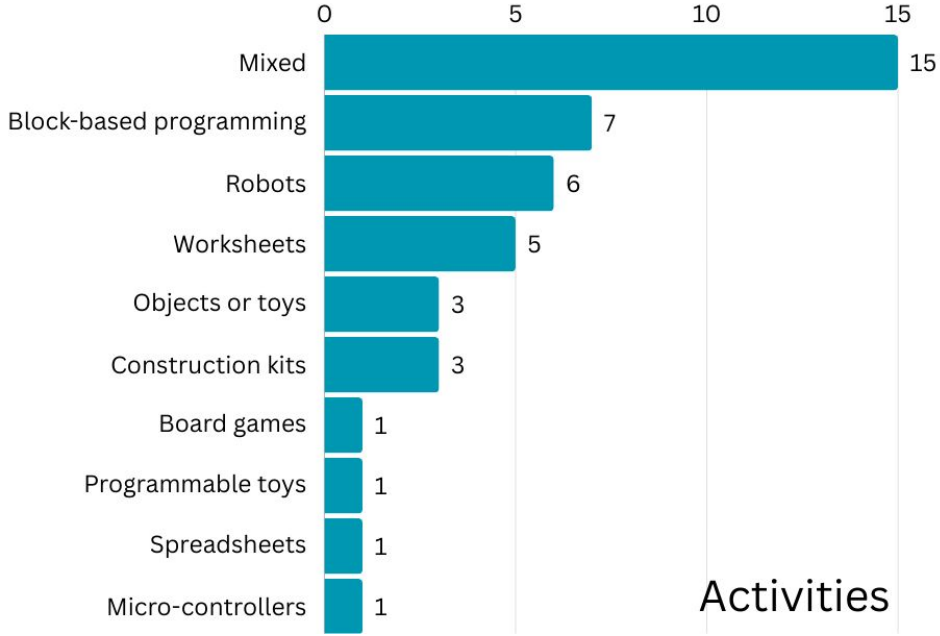
Procedure


Records identified through database searching (n=264)
Records after duplicate removal (n=214)
Records screened through abstract analysis (n=214)
Records excluded (n=120)
Full text articles assessed for eligibility (n=94)
Full text articles excluded (n=47)
Articles not available in full text (n=2)
Total number of articles included in review (n= 45)

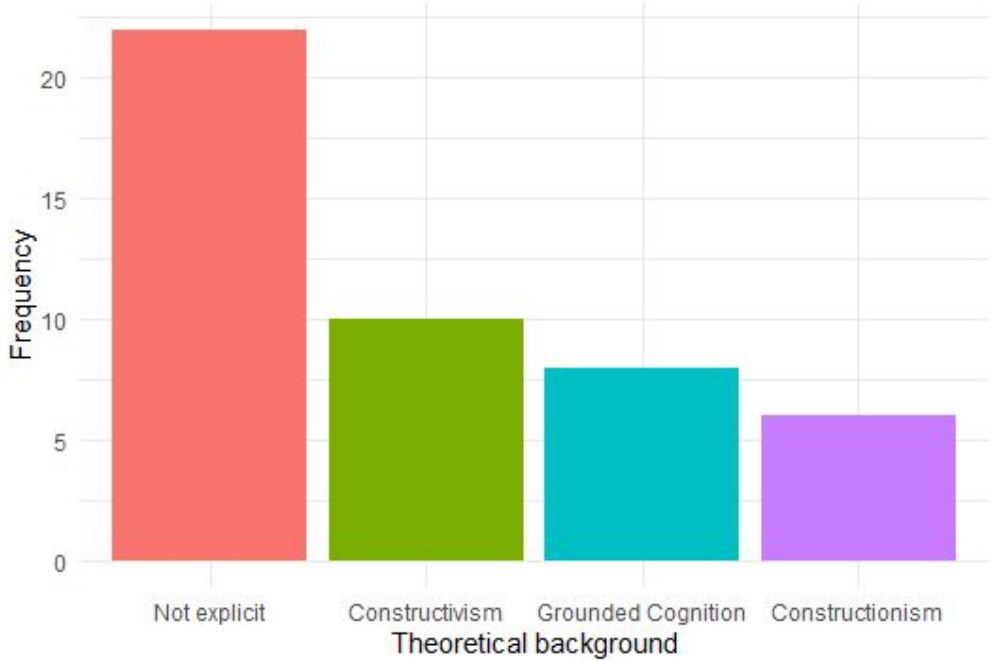
Findings

1. **What kind of grounded (i.e. physical and action-based) approaches have been researched in CS education for young learners?**

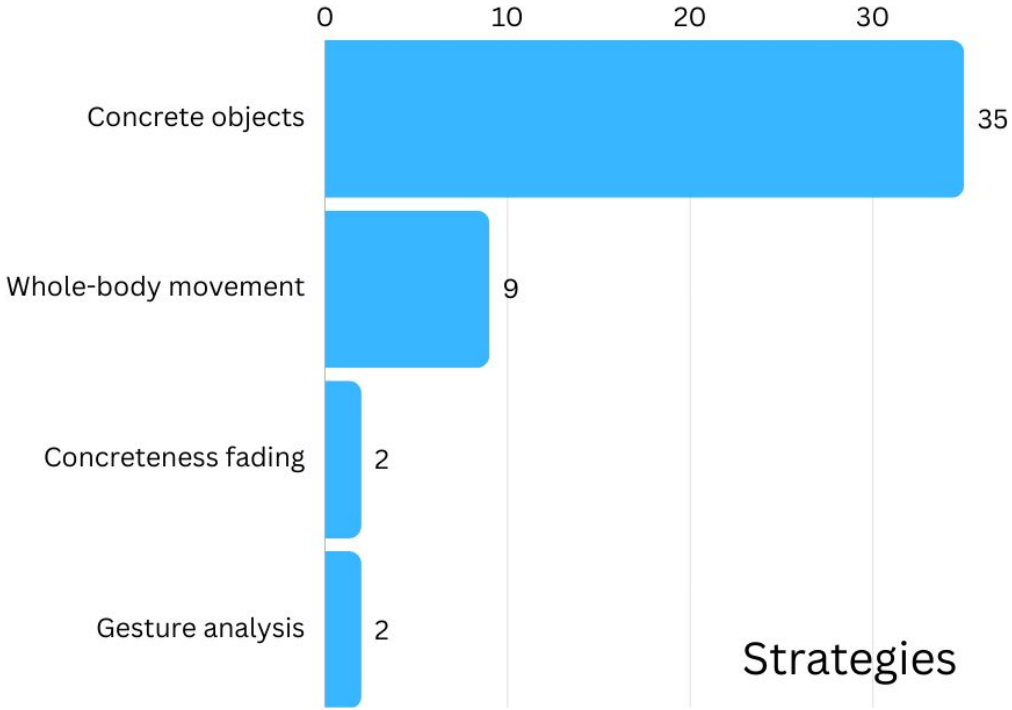
Categories	Sub-categories
Unplugged	Objects or toys Board games Worksheets
Phys. Comp.	Construction kits Programmable toys Robots Micro-controllers
Virtual	Block-based programming Spreadsheets
Mixed	None



2. Which theoretical background informs this research?



Findings



3. How is grounded cognition reflected in the activity design?

4. Outcomes

Learning outcomes: the study focuses on assessing conceptual learning (26)

Cognitive outcomes: cognitive outcome, where the study focuses on assessing gains on a specific cognitive skill (14)

Motivational outcomes: the study focuses on student's self-efficacy, self-reported motivation or enjoyment during tasks (22)

Findings

- The findings revealed ambiguity between instructional design and the theoretical foundations employed by researchers, often **influenced by technological availability**
- There was a strong emphasis on the role of concrete materials in promoting learning, while practices like concreteness fading, gesture analysis, or whole-body movement incorporation were less frequently reported.

Theory and practice

We selected a set of core concepts in early computing

SEQUENCES

REPETITION

SELECTION

EIFFEL model: empirical evaluation

- Our main objective is to have an **empirical evaluation** of the EIFFEL model in real world classrooms to test whether this model scaffolds conceptual understanding in young children

- In the refinement of the model, we designed a set of activities based on its principles

- The methodology involves a co-design process with early years teachers to ensure feasibility

Thank you

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