Extending Computational Thinking: Embodied Learning Through Socioenactive Scenarios

Emanuel Felipe Duarte[1], M. Cecília C. Baranauskas[2], and José A. Valente[3]

[1] Instituto de Computação, Universidade Estadual de Campinas, Brazil
[2] PPGInf, Universidade Federal do Paraná, Brazil
[3] Núcleo de Informática Aplicada à Educação, Universidade Estadual de Campinas, Brazil

Abstract

Although not always understood in the same way, the ideas of Computational Thinking have gained attention from policymakers in curriculum educational fields, particularly in primary math and K-12 education around the world, as necessary 21st-century skills to foster children's competence in problem-solving. In this work we argue that since its reappearance, many transformations have happened in the computational and social contexts, which make us rethink the literacies regarding computer-based environments. In this paper we extend the idea of computational thinking with a socioenactive perspective to computing, which considers a tripartite coupling of the physical, the digital and the social dimensions of ubiquitous computing based environments. We illustrate aspects of a socioenactive computational thinking with an analysis of two different scenarios. Results point out some aspects to be resumed from the origins of constructionism (for example, project action and body syntonicity) and others to be included in the subject (for example, sense-making, body affectivity and intersubjectivity).

Keywords and Phrases: ubiquitous technology, computing literacies, enactivism

1. Introduction

Emergent and ubiquitous technologies are increasingly an integral part of everyday life, which includes education in its many forms. As highlighted by the Cyberlearning Community Report (Roschelle, Martin, Ahn & Schank, 2017), learners develop their knowledge, skills, and identities across settings that are not limited to students in formal classrooms. In alignment with the report, we share the belief that a compelling way to explore computing education is by designing open possibilities for learning experiences composed by contemporary technologies, and experimenting with those designs in real-world educational scenarios. It is important to emphasize that by computing education we mean a general audience, from children to adults. Our focus, therefore, is not on Computer Science or Engineering programs, but on digital literacy as an indispensable competency in a society permeated by computational technology.

Duarte, E. F., Baranauskas, M. C. C., & Valente, J. A. (2025). Extending Computational Thinking: Embodied Learning Through Socioenactive Scenarios. *Constructionism Conference Proceedings, 8/2025*, 199–210. https://doi.org/10.21240/constr/2025/30.X

This view contrasts with traditional computational thinking approaches, which emphasize aspects such as abstraction to solve problems, control over the computer through logical commands, and debugging input and output relationships (Ezeamuzie & Leung, 2022). The current rise of Artificial Intelligence technologies with non-deterministic characteristics and natural language interfaces, albeit in a disembodied way, place emphasis on how traditional computational thinking approaches are not enough to deal with contemporary technology. We argue that instead of focusing on abstraction, control and code debugging, computing education can be approached by means of social and embodied learning through action, dialogue, and coupled feedback cycles. In this direction, we present and discuss the concept of socioenactive computing education as a product of our approach.

We base our understanding of computing education on the enactive approach to cognition, which found its main reference in Varela et al. (1992). Seen from an enactive perspective, there is a bidirectional relationship between the cognitive being and its world, resulting from its activity of constructing meaning while acting in the environment (Fuchs & De Jaegher, 2009). Thus, living beings do not simply translate information from the environment into internal representations to be processed to provide a result. The ideas of the enactivist paradigm have proven valuable for understanding the relations of coexistence and mutual specification between humans and computers, as also pointed out by Kaipainen et al. (2011). Several socioenactive scenarios have been proposed and investigated in different educational contexts (Baranauskas et al., 2021, Caceffo et al., 2022, Baranauskas et al., 2023).

In this work, we present two complementary approaches to socioenactive computing education, to extend the idea of computational thinking with a socioenactive perspective to computing. First, we present the Wolf-Robot in an educational scenario, to illustrate a focused exploration of computational technology and embodied ways to control it guided by children in a ludic activity with clear rules and objectives (Valente et al., 2021; Caceffo et al., 2022). Then, we present the InstInt scenario, where free embodied exploration by children and adults alike catalyzes curiosity about Artificial Intelligence and how machines may react to our actions (Duarte, Gonçalves & Baranauskas, 2018; Mendoza, Duarte & Baranauskas, 2023). These scenarios were part of a long-term research project[1] developed to study the socioenactive interaction in environments based on pervasive and ubiquitous technology.

The text is organized as follows: Section 2 presents the fundamentals and origins of computational thinking, to show how it has changed along the time. Section 3 introduces a socioenactive perspective to computational thinking by illustrating it in the two different scenarios. Section 4 summarizes and discusses the main findings of the work, and section 5 concludes, pointing out paths for further research.

2. Background

Several understandings for "Computational Thinking" (CT) have been expressed by the communities on Informatics and Education, Mathematics Education, and Computer Science, since the expression first appeared in Papert's book in 1980 (Papert, 1980, p. 182). Although the expression is used in the book, he does not define or elaborate on it, relating it to how computers might affect the way people think and learn. The CT expression was then popularized by Wing many years later, in her 2006 and 2010 articles (Wing, 2006; Wing, 2010).

1 https://socioenactive.ic.unicamp.br/

In Wing's viewpoint (Wing, 2006) CT represents "a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" (p. 33). For her, CT is a fundamental skill we should add to reading, writing, and arithmetic, every child should be exposed to. CT draws on fundamental concepts of Computer Science (CS) and mental tools used in the field to tackle "problems" of different nature: from those well-defined to societal ones. It involves "reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation" (Wing, 2006, p. 33) by shaping the problem to fit the computing device that will run the solution. Several concepts from CS are described by Wing in her effort to characterize CT; to cite some of them we have thinking recursively, interpreting code as data and data as code, using abstraction and decomposition, choosing a representation for a problem or modelling its relevant aspects, modularizing it, applying heuristic reasoning etc. She observes that CS concepts and methods have changed the ways of thinking of many disciplines, for instance Statistics, transformed by machine learning algorithms, Biology through computational biology practice, Economy through game theory, among others. She also observes the word "algorithm" has entered the vocabulary not only of scientists but of everyone. This phenomenon of popularizing CT terms is much more visible nowadays with the use of social media and artificial intelligence (AI). Wing finishes her viewpoint listing of six characteristics of CT which define what it is and isn't. 1. CT is about conceptualizing, not programming (as CS is more than computer programming). 2. CT is a fundamental skill (not a mechanical routine). 3. CT is a way that humans (not computers) think. 4. CT complements and combines mathematical and engineering thinking (as CS draws on mathematical and engineering thinking). 5. CT is about ideas (not just artifacts). 6. CT is for everyone, everywhere. Four years after her impacted publication, Wing (2010) formalizes a definition for CT and lists the efforts done especially in CT in Education, after her first mention of the expression. Formally CT is "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (p. 1). Informally CT "describes the mental activity in formulating a problem to admit a computational solution. The solution can be carried out by a human or machine, or more generally, by combinations of humans and machines."

Since its reappearance, CT has received considerable attention from policymakers in curriculum educational fields, particularly in primary math and K-12 education around the world, as a necessary 21st-century skill to foster children's competence in problem-solving (Nordby, Bjerke & Mifsud, 2022; Kafai, Proctor & Lui, 2019). Despite the fuzzy interpretations for what CT means, the systematic review done by Nordby and colleagues on primary mathematics education found two categories of CT activities, one focusing on skills related to programming or coding (such as mainly sequencing, looping, conditionals, debugging, decomposition, and abstraction), and one on broader process-oriented activities (communication, creativity, exploration, and engagement). For the first set of activities, the actions involved programming through block-based virtual interface Scratch, or block-based interface to give instructions to a robot. Unplugged and hybrid-unplugged activities preceding coding, decomposition, debugging, and abstraction were also identified. As for the second set of CT activities, the authors indicate that feedback the students received from teachers and from other students about their approach to coding prompted them to reflect on, engage in, and explore creativity in their solutions. Still, the most prevalent activities are those focusing on programming skills, leaving room for investigation on the integration of mathematics. Overall, Nordby et al. (2022) conclude that approaching mathematics using both categories of CT activities identified by the study allows for a combination of the Papert's constructionist approach, in which children learn mathematics through discovery and engagement in computer activities (Papert, 1986), and Wing's (2006) emphasis on "thinking like a computer scientist" (p. 33).

Adding to the efforts of understanding CT to shape the future of K12-education in the 21st century, Kafai, Proctor and Lui (2019) identified three different framings for promoting CT, with emphasis on skills building, creative expression, and social justice, which they characterized as 1. Functionally oriented, 2. Situated or constructionist and 3. Critical or social justice oriented. The functional and most prominent framing draws from the cognitivist research tradition, which supports the pragmatic goals of skill and competence building, recognizes the role of computers in problem-solving and emphasizes their skillful individual use. The situated framing, which draws from constructionist learning theory (Papert, 1986), emphasizes designing and programming digital artifacts as personal expressions that are shared on social networks; thus, computation is something that can also grant power and agency. The critical or justice-oriented framing, which draws from the traditions of critical pedagogy (Freire, 1993), emphasizes analysis of the relationship between media and oppressive power structures, as well as youth agency through the process of creating and disseminating media content. The authors propose to integrate these different perspectives as literacies needed for the 21st century.

From Papert and Wing to more recent discussions on CT, many transformations are happening in the computational and social scenarios, which make us rethink CT. For example, the artificial intelligence agents embedded invisibly in our interaction with technology, computer systems ubiquitous and pervasive in our environment, challenges to deal with social media and fake news, privacy and many more issues, adding much more complexity to a reflection on what we really need to consider as literacies for children's future. For Kafai et al. (2019), "any emphasis on computational literacies should equally consider not only what competencies students can acquire, but also how to create awareness of the ways the use and design of computational media can simultaneously oppress and inspire" (p. 4). In this paper, we draw on phenomenological (socioenactive) inspiration to revise some of these ideas while suggesting other aspects of social enactive computational literacies of the near future.

3. Computational Thinking in Socioenactive Scenarios

Taking an enactive perspective towards computational systems, and considering contemporary ubiquitous and pervasive technologies, Socioenactive Scenarios are characterized by a tripartite coupling between social, physical and digital dimensions (Baranauskas et al., 2021, Caceffo et al., 2022, Baranauskas et al., 2023). The scenario, therefore, goes beyond a single person interacting with a computer (e.g., a User Interface), instead, it is composed of multiple people interacting, in an embodied way, with each other and with computational technologies present in the environment. In the following, we present two practical and varied instances of socioenactive scenarios: Wolf-Robot and InstInt. As mentioned in the Introduction section, we selected these scenarios because they offer different perspectives to understand computational thinking: one more goal-oriented and the other more open-ended and exploratory.

The main aspects of these two scenarios are synthesized in Table 1. The ethical approval for these studies was obtained from University of Campinas' Research Ethics Committee in October 2017, under number CAAE: 72413817.3.0000.5404.

Scenario	Context	Number of Participants	Participants Details	Technology	Interaction Dynamics
Wolf-Robot	School	26	Children between 4 and 5 years old	Interactive robot	Goal oriented activity of guiding the robot to a target location through body actions and coordination
InstInt	Museum	9	Children between 6 and 13 years old	Interactive installation	Exploration oriented activity of experiencing the installation and its behavior with a group of other people

Table 1: Synthesis of the studied scenarios.

3.1 Focused Exploration: The Wolf-Robot Scenario

The wolf-robot scenario was a workshop that recreated the Little Red Riding Hood fable with ubiquitous technology (Valente et al., 2021; Caceffo et al., 2022). The workshop was conducted at the University of Campinas' Divisão de Educação Infantil e Complementar (DEdIC), and involved two classes with a total of 26 children between 4 and 5 years old. In this scenario, the "scene" represented the enchanted forest, characterized by the yellow rectangle. The other elements in the scenario were the wolf (a characterization for the robot), the rangers (children wearing boots), the forest trees (children alongside the stage), and the Grandma's "Laboratory" (represented by a black spot on the floor). The robot embedded technology (sensors and actuators), being an artifact capable of moving forward and backing off and randomly changing direction when it found something blocking its path (e.g., children's boots, children in the role of forest trees delimiting the stage).

At each moment, a group of 4 children, acting as rangers, had the role of guiding the wolf to reach Grandma's lab so that its GPS could be fixed. Another group (the class' remaining children), positioned around the "forest", had the role of preventing the wolf from leaving the scene, the enchanted forest in the story. This was done by positioning their feet as obstacles to be avoided by the robot, changing its position and direction. If they succeeded, a strong applause sound was played through a hidden notebook. In the situation of escaping, a "car crash'" sound was played (on the hidden notebook), which means they failed as a group to finish the task. To complete the task, the children needed to communicate and coordinate their actions on the fly. The children sitting around the scene were acting like trees. They were instructed to play the role of "enchanted trees", staying seated in their positions and moving only when required to place their boots in the robot path, thus helping the rangers to prevent the wolf from leaving the forest. Although they had a different role from the rangers, they were not just spectators as they engaged in coordinated action with the others towards enacting the narrative. Figure 1 illustrates this scenario.

In this scenario, traditional computing education aspects such as abstraction, control, and debugging give place to embodied action and real-time coordination through gestures, expressions and verbal communication. Albeit being technologically simple, the wolf-robot as a computational system is not explicitly controlled or programmed by the children to reproduce a predetermined outcome. Instead, based on a post-workshop debriefing with the children, they described understanding the robot as a computational system with its own behavior – one that can be interacted with socially and played with to achieve a goal.

Figure 1: Children interacting with the Robot Wolf, and children around the "forest".

3.2 Free Exploration: The Instint Scenario

The InstInt (Duarte, Gonçalves & Baranauskas, 2018; Mendoza, Duarte & Baranauskas, 2023) is an interactive installation that allows children and adults alike to dynamically create a sound composition by touching five luminous ribbons that trigger sounds from specific musical instruments, such as drums, flute, organ, clavinet, and bass, while the installation moves. It was experienced by 9 children between 6 and 13 years old accompanied by their legal guardians, in a workshop conducted at the University of Campinas' Exploratory Science Museum on February 17, 2022. The electromechanical structure is approximately 10 feet tall and consists of a central mast anchored to the floor and ceiling, a top hat-like umbrella structure from which five touch-sensitive luminous ribbons hang, as well as other components like a central computer, motors, bearings, pulleys, and power supplies. The luminous ribbons are LED strips covered with a fabric embedded with conductive thread, making the ribbons responsive to touch. Additionally, the installation moves due to its electromechanical structure, which rotates.

Initially, the installation's umbrella is closed, and it remains stationary while soft background music plays at a low volume. When people approach, motion sensors built into the installation detect their presence, causing the umbrella to open, the background music to become livelier, and the structure to start rotating. Visitors can interact with the installation by touching any of the five ribbons hanging from the umbrella. When touched, the ribbons activate musical instrument sounds that blend with the background music, produce colorful lighting effects with their LEDs, and project visuals onto the floor, creating an immersive audiovisual experience. When multiple people interact with the installation simultaneously, the music progressively becomes more cheerful and energetic as they collaborate and coordinate new touch sequences on the ribbons. In sync with the music, the lights, projections, and rotational movements also respond dynamically to how the ribbons are played, providing varied feedback. Some ribbons are positioned higher and can only be reached by adults, while others are lower and more accessible for children. When people leave the installation, the lights and projections gradually dim, and the sound effects become softer. Figure 2 illustrates this scenario.

We observed that the embodied interaction of approaching the installation, touching ribbons and coordinating actions with other participants did not yield a perceived control over the installation due to its deliberate abstract nature. Instead, the interaction nurtured curiosity and reflection about how presence and (coordinated) actions impact the installation. The embodied interaction also nurtures reflection about how intelligence can be perceived in computational systems, and how they may "feel" about and react to our actions. In the promotional material for the workshop, it was hinted to the public that the installation presents some kind of intelligence, and in a debriefing session after the interaction, the children were invited to talk about their perceptions of intelligence in InstInt and other computational systems. Most notably, the children agreed among themselves that InstInt presents some kind of intelligence. And although they attributed this intelligence mainly from InstInt having a computer that was programmed, the children talked about how they do not see the same intelligence in conventional computers, and when further questioned on the subject, they highlighted the importance of lights and movement as experienced during the interaction.

Figure 2: Children and adults interacting with InstInt.

4. Towards Socioenactive Computational Thinking

The presented scenarios allow us to think about computational thinking beyond how it is traditionally understood (practical, situated and critical framings, as presented in Section 2), towards what we call socioenactive computational thinking. In this effort we are not denying past framings and contributions of computational thinking research, as they are also present in our presented scenarios to some extent, but rather expanding on it. Table 2 summarizes the results of the two scenarios presented in this paper, highlighting aspects of what we understand as socioenactive computational thinking.

By *Project as (en)Action* we mean, besides the "hands on, heads in" from Ackermann's interpretation of constructionism (Ackermann, 2001), the children's bodies are included in the actions that are performed to a desired configuration of a "solution" (e.g., the robot's changes in direction, the installation movements). Although code or project debugging are usually individual activities of computational thinking, we mean *Debugging as Sense-making*, a process dynamically conducted by the group of children in their joint action, a social process. *Body Syntonicity*, a concept first observed by Papert, is illustrated through children's physical interaction with the Logo Turtle. While body syntonicity has been studied in learning contexts (Danish & Enyedy, 2020; Danish et al., 2020), its role in computational thinking remains largely unexplored. The physical-digital coupling of elements, compounding the new scenarios, make this aspect explicit and valuable through the involvement of the children's whole body in the performed actions. Children's bodies not only are part constituent of their performance, but are also vehicles of expression for their Affection while acting, hence *Body Affectivity*. Last but not least, a child is not alone in the scenario; *Intersubjectivity* in relations with other participants and artifacts influences and guides their perception and action in the scenario.

	Wolf-Robot	InstInt
Project as (en)Action	The robot is the focus of attention, but the actions of other participants are also important. By focusing on collaboration and coordinating their actions, the children can filter strategies to help them achieve their goal. In this sense, the children do not develop a preconceived algorithmic solution to leading the robot, but rather dynamically and socially make an embodied algorithm emerge through their coordinated actions.	With no explicit problem to be solved the general goal of exploration leads to experimenting with different individual and coordinated actions (e.g., two people touching ribbons at the same time). What is important and should be the focus of attention in the activity is not predetermined, but rather decided by the participants themselves through their embodied sense-making process of exploring the interactive installation.
Debugging as Sense-making	The behavior of the Robot Wolf is not direct, as it may randomly turn left or right when avoiding obstacles, therefore the children have to try different actions and sequences of actions to guide it. During this interaction, children constantly anticipate successful or unsuccessful situations regarding positioning their bodies to lead the robot.	As the behavior of InstInt is not easily understood as a relation of inputs and outputs, participants make sense of the scenario through their afforded social interactions with the installation and their expectations of "intelligent systems" (e.g., coordinating to touch two ribbons at the same time and interpreting how the installation behaves).

	Wolf-Robot	InstInt
Body Syntonicity	Instead of "hands on, heads in", we could use "bodies in", as children are acting in the agreed narrative of leading the Robot Wolf to Grandma's lab, with the joint and coordinated movement of their bodies.	The Instint installation has a "body" which moves according to the ways people move and touch the ribbons beneath it. The whole scenario changes (light, sound, movement) according to people's actions.
Body Affectivity	As the full bodies (children's and robot's) are involved in the performance, they affect and are affected by each other and by the scenario elements. Expressions of their emotional states, their mood while acting, are part of the performance too.	The structure of InstInt, which resembles something like an umbrella and a carousel, affords people to approach the installation and position themselves beneath it. Its movement, in turn, affords people to move accordingly, enacting expressions and emotional states along with and through their movement.
Inter-subjectivity	The activity in the scenario is based on the narrative of the Robot-Wolf and by accepting the role play. Children's actions towards their peers seem to be naturally conductive to their coordination (e.g., when children articulate among themselves trying to keep the robot inside the enchanted forest, preventing it from escaping).	The InstInt installation naturally affords the coordinated actions of people, as they follow the circular movements of the installation altogether, while also holding the ribbons. Moreover, they are talking to each other, listening to the underlying installation sound and paying attention to the movement of the others.

Table 2: Aspects of Socioenactive Computational Thinking in the two scenarios.

As ubiquitous technologies increasingly become integrated with our daily lives, education in general is also bound to be transformed by novel technologies. It may be tempting to perceive the recent surge of interest in Artificial Intelligence applications as a way to integrate these technologies into educational processes. We, however, cannot ignore how it is through embodiment that learners develop their knowledge, skills, and identities across settings. In this paper, we present two complementary socioenactive scenarios where children can enact and reflect upon aspects of computing education that go beyond objective problem-solving and traditional computational thinking approaches.

In a socioenactive computing approach, traditional computational thinking concepts such as abstraction, control, and debugging may still be present, but they are not a central point of the interaction. As technology becomes increasingly more ubiquitous, integrated into everyday life, and (supposedly) intelligent, digital literacy requires not only those computational thinking skills, but also the ability to perform in an enriched technological environment, experience its capabilities, and make sense of physical-digital technology in everyday social life. In our approach, these skills are explored in social and embodied scenarios, designed to create open possibilities for learning experiences constituted by contemporary technologies.

In the presented socioenactive scenarios, joint attention and joint action allowed emergent collaboration, constituting a process of participatory sense-making of contemporary computational technology. This sense-making extends computational thinking as it is traditionally understood, towards an understanding of a project children engage in as (en)acting together an agreed narrative, making sense of it in an embodied way.

The way we currently use technology in our body, for example by using a smartwatch to capture our body data, or a mobile phone to count our daily steps, is changing our perception of how technology works and modifying our ways of thinking about our own bodies. Furthermore, the social aspects of these captured data allow sharing, comparing etc., also changing our perception about our bodies and actions towards others. Even the technical level of using computer systems, such as programming, should be put into perspective in this current state of technological development. Abstraction, decomposition, debugging, and other traditional computational thinking concepts continue to be important skills, however other abilities are now (re-)emerging such as tools bricolage, information navigation, code mashups, data curation, etc.

The presence of the body in considerations of our relation with technology is not at all new (see for example Ackermann, 1999). Nevertheless, the new technologies and ways of living with them make us rethink the body in relation to technology. We do not mean to understand the human body with the goal to simulate it in the physical-digital artifacts, but rather to understand our bodies by acting with others and with the artifacts (who also have synthetic bodies of their own).

5. Conclusion

What has been historically discussed as Computational Thinking has a strong relation to the model of Computing, as conceptualized in the creation of this discipline. Within this tradition the emphasis was on coding skills and several aspects related to mathematical thinking (e.g., abstraction, decomposition, algorithm). Nowadays, technology ubiquity has changed the ways of experiencing computers, leading to new ways of perceiving computational technology and making sense of it. In this paper, we used two different scenarios to illustrate some socioenactive experiences of people (children) with contemporaneous computer technology. We aimed at extending computational thinking with new aspects emerging from the embodied interaction in these technological environments.

The analyzed scenarios resulted in some aspects of socioenactive computational thinking that deserve consideration regarding the evolution of the computer and its effects on people's lives. These aspects, highlighted in Table 2, encompass: 1. the understanding of a "project" based on the actions/performance of children in the particular scenario (*project as (en)action* is a wordplay to refer to the underlying concept of "enaction"); 2. Debugging is understood as the interplay of moving/acting with the scenario/artifacts changes (*debugging as sense-making*); 3. That movement is accomplished through *body syntonicity* of people/children in their performance with the artifact/scenario; 4. Their bodies emotionally affect and are affected by the sintony of people and the scenario's artifacts (*body affectivity*); and 5. Their performances are not *ad hoc* movements, but are joint and coordinated acts (*intersubjectivity*), as each one considers and articulates their actions with those of the others in the scenario playing. While some concepts, such as debugging, sense-making and body syntonicity, are not new, our contribution lies in reframing them through an enactive lens to better understand computational thinking in a contemporary technological context. Further work involves understanding social performance in embodied learning contexts, which are more and more present in scenarios of ubiquitous computing. Moreover, this can be materialized by including the embeddedness of technology in our body (e.g., clothing, or even the implant of it in our bodies).

Acknowledgements

This work was partially funded by the University of Campinas (FAEPEX grant #2356/24), and the National Council of Technological and Scientific Development (CNPq), grants #310854/2019-9 and #309442/2023-0.

References

Ackermann, E. (1999). Enactive representations in learning: Pretense, models, and machines. In B. Bliss, R. Säljö, & P. Light (Eds.), *Learning sites: Social and technological resources for learning* (pp. 144-155). Pergamon. https://www.academia.edu/17860759/Enactive_Representations_in_Learning_1999_

Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference? *Future of Learning Group Publication*, *5*(3), 438. https://learning.media.mit.edu/content/publications/EA.Piaget%20_%20Papert.pdf

Baranauskas, M. C. C., Duarte, E. F. & Valente, J. A. (2023). Socioenactive Interaction: Addressing Intersubjectivity in Ubiquitous Design Scenarios. *International Journal of Human–Computer Interaction*, *40*(13), 3365–3380. https://doi.org/10.1080/10447318.2023.2188536

Baranauskas, M. C. C., Mendoza, Y. L. M. & Duarte, E. F. (2021). Designing for a socioenactive experience: A case study in an educational workshop on deep time. *International Journal of Child-Computer Interaction*, *29*, 100287. https://doi.org/10.1016/j.ijcci.2021.100287

Caceffo, R., Gonçalves, D. A., Bonacin, R., dos Reis, J. C., Valente, J. A. & Baranauskas, M. C. C. (2022). Children's social interactions within a socioenactive scenario. *Computers & Education*, *176*, 104324. https://doi.org/10.1016/j.compedu.2021.104324

Danish, J. A., & Enyedy, N. (2020). Constructing with and through the Body. In N. Holbert, M. Berland & Y. B. Kafai (Eds.), *Designing Constructionist Futures: The Art, Theory, and Practice of Learning Designs* (pp. 245-254). The MIT Press. https://doi.org/10.7551/mitpress/12091.003.0031

Danish, J. A., Enyedy, N., Saleh, A., & Humburg, M. (2020). Learning in embodied activity framework: a sociocultural framework for embodied cognition. *International Journal of Computer-Supported Collaborative Learning*, *15*(1), 49-87. https://doi.org/10.1007/s11412-020-09317-3

Duarte, E. F., Gonçalves, F. M. & Baranauskas, M. C. C. (2018). Instint: Enacting a small-scale interactive installation through co-design. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction* (pp. 338-348). https://doi.org/10.1145/3292147.3292158

Ezeamuzie, N. O. & Leung, J. S. (2022). Computational thinking through an empirical lens: A systematic review of literature. *Journal of Educational Computing Research, 60*(2), 481-511. https://doi.org/10.1177/07356331211033158

Freire, P. (1993). *Pedagogy of the oppressed* (20th anniversary edition). Continuum.

Fuchs, T. & De Jaegher, H. (2009). Enactive intersubjectivity: Participatory sense- making and mutual incorporation. *Phenomenology and the Cognitive Sciences, 8*(4), 465–486. https://doi.org/10.1007/s11097-009-9136-4

Kafai, Y. B., Proctor, C. & Lui, D. A. (2019). Framing Computational Thinking for Computational Literacies in K-12 Education. *Proceedings of the Weizenbaum Conference 2019 "Challenges of Digital Inequality – Digital Education, Digital Work, Digital Life"* (pp. 1-6). Berlin https://doi.org/10.34669/wi.cp/2.21

Kaipainen, M., Ravaja, N., Tikka, P., Vuori, R., Pugliese, R., Rapino, M. & Takala, T. (2011). Enactive Systems and Enactive Media: Embodied Human-Machine Coupling beyond Interfaces. *Leonardo, 4*4(5), 433–438. https://doi.org/10.1162/LEON_a_00244

Mendoza, Y. L. M., Duarte, E. F. & Baranauskas, M. C. C. (2023). I*nstInt: Design e Desenvolvimento de uma Instalação Socioenativ*a (IC-23-07). Instituto de Computação, Universidade Estadual de Campinas. https://ic.unicamp.br/~reltech/2023/23-07.pdf

Nordby, S. K., Bjerke, A. H. & Mifsud, L. (2022). Computational Thinking in the Primary Mathematics Classroom: a Systematic Review. *Digital Experiences in Mathematics Education, 8*, 27–49. https://doi.org/10.1007/s40751-022-00102-5

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Papert, S. (1986). *Constructionism: A new opportunity for elementary science education*. Massachusetts Institute of Technology, Media Laboratory. https://dailypapert.com/wp-content/uploads/2021/02/Constructionism-NSF-Proposal.pdf

Roschelle, J., Martin, W., Ahn, J. & Schank, P. (2017). *Cyberlearning community report: The state of cyberlearning and the future of learning with technology*. SRI International. https://circlcenter.org/wp-content/uploads/2017/07/CyberlearningCommunityReport2017.pdf

Valente, J. A., Caceffo, R. E., Bonacin, R., Reis, J. C., Gonçalves, D. A. & Baranauskas, M. C. C. (2021). Embodied-based Environment for Kindergarten Children: revisiting constructionist ideas. *British Journal of Educational Technology, 52* (3), 986-1003. https://doi.org/10.1111/bjet.13078

Varela, F. J., Thompson, E. & Rosch, E. (1992). *The Embodied Mind: Cognitive Science and Human Experience*. Cognitive science: Philosophy, psychology. The MIT Press.

Wing, J.M. (2006). Computational Thinking. *Communications of the ACM, CACM 49*(3), 33-35. https://doi.org/10.1145/1118178.1118215

Wing, J. M. (2010). *Computational thinking: What and why?* Carnegie Mellon University. https://www.cs.cmu.edu/~CompThink/papers/TheLinkWing.pdf