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Algorithms in the city: computational thinking from the perspective of Bilingual and OnLIFE Education

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Abstract:
Experiencing the city as a learning space implies recognizing it as a living, complex, and communicative entity. It means understanding it through the intertwining of its various times, spaces, and dimensions: human and non-human; digital, biological, cultural, technological, social, historical, economic, among others. This article presents a pedagogical practice that emerged from a doctoral thesis in the context of Bilingual Education, which problematizes ways of knowing and producing knowledge related to the development of computational thinking in the city. The experiences were developed from the perspective of inventive learning, the CLIL approach, and OnLIFE Education. As a research method, it adopts the cartographic method of intervention research for data production and analysis. The results are grounded in elements present in reticular and connective epistemologies, inventive cognition, and the concepts of mathetics and Bilingual Education. These findings suggest that computational thinking is being enhanced through experiences and explorations of the city, contributing to its interdisciplinary and transversal understanding. They point to the emergence of a new cognitive policy in education, one that is more connected with life, and that implies rethinking the curriculum and teacher training.

Keywords:
Computational thinking; bilingual education; OnLIFE

Resumo:
Vivenciar a cidade enquanto espaço de aprendizagem implica reconhecê-la como uma entidade viva, complexa e comunicativa. Trata-se de compreendê-la no entrelaçamento de seus múltiplos tempos, espaços e dimensões — humanas e não humanas, digitais, biológicas, culturais, tecnológicas, sociais, históricas, econômicas, entre outras. Este artigo apresenta uma prática pedagógica oriunda de uma tese de doutorado no contexto da educação bilíngue, que problematiza formas de conhecer e produzir conhecimento relacionadas ao desenvolvimento do pensamento computacional na cidade. As experiências foram desenvolvidas sob as perspectivas da aprendizagem inventiva, da abordagem CLIL e da Educação OnLIFE. Para a produção e análise dos dados, a pesquisa se apropria do método cartográfico de pesquisa-intervenção. Os resultados fundamentam-se em elementos das epistemologias reticulares e conectivas, da cognição inventiva e dos conceitos de matética e bilinguismo. Indicam que o pensamento computacional é potencializado nas formas de vivenciar a exploração da cidade, contribuindo para sua compreensão interdisciplinar e transversal. Esses achados apontam para a emergência de uma nova política cognitiva em Educação, mais conectada com a vida, o que implica repensar o currículo e a formação docente.

Palavras-chave:
Pensamento computacional; educação bilíngue; OnLIFE

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INTRODUCTION

The experience of strolling through the city is an adventure in exploration, provoking discoveries, new perspectives, and observations. According to La Rocca (2018), the city is a vast and unlimited reservoir of experiences, a container of life that offers us a variety of stimuli and sensations.

Di Felice (2009) argues that environment and territory should not be understood as things, but as something alive, a complex, active, and communicative entity. It is the intertwining of all its dimensions that gives it shape: its various times and spaces, its different spheres of physical, digital, spiritual, human, and biological life, a meeting place for people, nature, knowledge, technologies, products, traditions, and cultures.

This understanding offers a vision of a networked dialogue with different entities, whether biological, physical, or digital. In these networks, digital technologies expand our presence in the city and establish new forms of habitation and communication. With these technologies, it becomes possible to connect in various ways to this living body that is the city and to engage with multiple physical and/or digital spaces, across synchronous and asynchronous times, transforming communication flows from unidirectional to multidirectional.

According to Megale (2019a), such communication flows, from the perspective of bilingualism, have generated complex, mobile, social, and communicative environments, as well as a multicultural formation that enables individuals to navigate different cultures and contexts.

In view of this reality, there has been a growing expansion of Bilingual and Multilingual Education in the Brazilian educational context. Megale e Liberalli (2021) argues that this type of education must be understood by considering the multidimensional development of the two or more languages involved, the promotion of knowledge between them, and the appreciation of translanguaging as a means of constructing an understanding of the world for bilingual subjects. According to the author, Bilingual Education creates a space for the ascent of knowledge that fosters intercultural awareness, and its central objective should be to facilitate dialogue between knowledge systems and behaviors constructed on distinct, and at times conflicting, cultural foundations.

In addition to promoting diverse knowledge through the languages of instruction, the development of greater cultural and linguistic awareness (Megale; Liberalli, 2021) can support the ability to value diversity — both human and non-human. Furthermore, such awareness can encourage the sharing of spaces that transcend physical and geographical boundaries.

In this context, we witness the evolution of artificial intelligence, robotics, the Internet of Things, wearable technologies, big data, nanotechnology, among others — all of which are transforming contemporary life and making it increasingly connected. This allows us to affirm that we now inhabit a hyperconnected reality (Floridi, 2015) in which it no longer makes sense to separate "online" from "offline."

[1] Reviewed by: Fernanda Montenegro.

We live, according to Floridi (2015), in an *onlife* society, where digital technologies are neither "external" to us nor fully subject to human control. This understanding, as noted by Moreira and Schlemmer (2020, p. 26), makes it possible to "envision/design different investigative, development, and training contexts, which stimulate inventiveness in the realm of teaching and learning." The act of inhabiting and co-inhabiting has become increasingly atopic[2], linked not only to geographical spaces, but also to networked digital spaces.

The transformation of any type of surface into binary code and data, as argued by Menezes, Schlemmer and Di Felice (2024), transubstantiates and expands the possibilities for interaction with and within the world of atoms and carbon. We inhabit a world composed not only of physical and geographical realities, but also of digital realities, data, materialities, biodiversity, cultures, and physical and connected surfaces. Thus, in reflecting on this reality within the context of Bilingual and Multilingual Education, knowledge of additional languages provides access to the universe of these multiple discourses. It enables individuals to understand the world they are part of, develop metalinguistic skills, and build a critical view of sociocultural aspects.

From this way of inhabiting, increasingly permeated by digital networks and diverse technologies, emerges the interest in the development of computational thinking in education — which is considered a fundamental literacy in the 21st century by Wing (2006). Through computational thinking, technologies that connect human and non-human entities, cultures, and languages take form. This raises the question: how is the development of such thinking related to Bi/Multilingual Education?

Therefore, this article aims to present and discuss the pedagogical practice entitled *Coding the Fachwerk*, which is part of a set of teaching practices developed within the doctoral dissertation *Tracing Algorithms through the City: Cartography of the Development of Computational Thinking from an OnLIFE Education Perspective*, conducted in the context of Bilingual Education. The practice, which is the focus of this article, aims to articulate the development of computational thinking (CIEB, ,2018; Csizmadia *et al*., 2015; Papert, 1980, 1994; Papert; Solomon, 1971; SBC, 2019; Wing, 2006, 2008, 2017; Wing; Stanzione, 2016) and the process of understanding and constructing algorithms linked to the cybrid territory of the city. It seeks to orchestrate, under a theoretical-epistemological framework, the hybridization of urban and post-urban spaces (Di Felice, 2009, 2012, 2017, 2018; La Rocca, 2016, 2018), inventive cognition (Kastrup, 2001, 2010, 2015), bilingualism and Bilingual Education (Megale, 2019a, 2019b; Megale; Liberali, 2016, 2021), learning projects in the CLIL approach (Coyle, 2008; Souza, 2019), and the OnLIFE Education perpective (Schlemmer, 2021; Schlemmer; Moreira, 2020, 2022). The following section presents the theoretical foundation that underpins this pedagogical practice.

COMPUTATIONAL THINKING AND THE EMERGENCE OF OnLIFE EDUCATION

We can assert that we live in a hyperconnected reality, which has brought to the forefront of debates within both the scientific community and the technology industry the importance and necessity of developing computational thinking in education from early childhood. Wing (2006), in initiating this debate by introducing the term *computational thinking* in her seminal article, argued that it constitutes a fundamental literacy for living, coexisting, and acting in the 21st century. The publication of Wing's (2006) article, in which computational thinking is presented primarily as the ability to solve problems based on principles of computer science, generated significant discussion within the scientific community. However, this notion is not entirely new. Papert e Solomon (1971) e

[2] The term *atopic* derives from the Greek *a-topos*, meaning "out of place" or "without place." In his work, Di Felice (2009, 2012, 2017, 2018) employs this term to refer to a mode of inhabiting that is not tied to a fixed geographical space, but rather occurs in interconnected, hybrid, and digital spaces.

Papert (1980, 1994) had already, albeit without using the term itself, associated computational thinking with *thinking by procedures* (procedural thinking). His research led to the development of the LOGO language and its underlying philosophy, conceived in the late 1960s and popularized during the 1980s.

Wing (2006) emphasizes that computational thinking will be fully integrated into our lives when terms such as *algorithm*, become part of everyday language. Achieving this integration, however, requires individuals to engage in the creation and execution of algorithms in diverse ways, thereby building elements that foster critical reflection on these processes. In this way, it becomes possible to incorporate the meaning of computational thinking beyond its technical and utilitarian dimensions, embracing its inventive potential from a critical, conscious, and responsible perspective.

The literature review based on Wing's (2006) article enabled a broader and more nuanced understanding of the conceptual scope of computational thinking. Between 2006 and 2017, Wing revisited the discussions on computational thinking and refined the concept. The author highlights that elements of computer Science, including abstraction, decomposition, data representation, variables, recursion, debugging, and modeling, are integral to computational thinking. Nonetheless, these elements are not exclusive to computer science, as they are pervasive and transversal across various fields. Morin (2007, 2015), for instance, conceives of thinking in its complexity, attributing to it a dialogical, recursive, and holographic mode of expression. There is an ongoing dialogue between part and whole, in which the part isolates itself in order to connect, in a recursive process whereby parts and effects return to the whole, the whole feeds on the parts, and the essence of the whole resides within each part.

Based on this debate within the scientific community, several international documents have discussed and aligned the premises of computational thinking in education. Notable among these are contributions from the ISTE (International Society for Technology in Education), the CSTA (Computer Science Teachers Association), (ISTE; CSTA, 2015), and the NRC (National Research Council, 2010) in the United States, as well as the Royal Society (Britain, 2012), in the United Kingdom. In Brazil, efforts to incorporate computational thinking into Basic Education have been supported by documents from the SBC (Brazilian Computer Society) and the CIEB (Reference Curriculum in Technology and Computing), aimed at integrating computational thinking into the Base Nacional Comum Curricular – BNCC *(National Common Core Curriculum)* (Brasil, 2017).

However, within the context of Brazilian education, the National Common Core Curriculum explicitly mentions the term *computational thinking* only concerning the development of mathematical skills during the final years of elementary school. Recognizing the importance of fostering computational thinking in education involves understanding that we live in an era marked by the algorithmizing of the world. This awareness prompts the educational field to conceive of computational thinking as transversal and interdisciplinary—a dynamic force embedded in processes of becoming and inquiry, operating within networks, transcending the human, and generating connections in constant motion, far removed from centralities and dualisms such as subject–object, subject–technology, or subject–environment.

According to Resnick (2009), a researcher at MIT and a former Papert's student, although young people interact with digital technologies continuously, not all of them know how to create their own games, animations, or simulations. For the author, this situation is akin to knowing how to read but not how to write. This observation underscores an important issue: in this context, we witness far more consumption of technology than creation. As Resnick (2009, p. 62) asserts, "we need to expand the notion of 'digital fluency' to include designing and creating, and not just navigating and interacting."

In this regard, programming constitutes a means of materializing computational thinking, and among the various possibilities for its development is the programming of algorithms using

block-based coding on digital platforms, which attract children due to their playful and engaging interface.

Programming represents a form of expression and expands the repertoire of possibilities for creation and learning. It is grounded in computational thinking, which is based on principles of computer science and on the capacity to reflect upon one's own approach to problem-solving. The act of programming acquires greater meaning when aligned with Papert's[3] (1980) principle of *mathetics*, which advocates that learning experiences should be meaningful to learners. From this perspective, the author, drawing on his research with the LOGO language and philosophy, argued that students should be afforded opportunities to explore and construct their own knowledge through experiences that are relevant and significant to them.

Thus, understanding computational thinking as something that develops and is strengthened through digitality, connectivity, *mathetics*, and the hybridization of spaces constitutes a problematization of contemporary times that also challenges us to reflect upon and construct a new cognitive policy in education. This challenge contributes to the emergence of an *OnLIFE* Citizen Education (Schlemmer, 2021), experienced within reticularity, through the continuous connectivity between humans and non-humans in an increasingly digitalized and connected world.

The concept of *OnLIFE* Education, according to Schlemmer (2021), has been shaped within the research–development–training triad of the International Research Group on Digital Education (GPe-dU UNISINOS/CNPq). It is grounded in the concept of Hybrid and Multimodal Education (Schlemmer, 2016), which provided the foundation for conceiving and developing inventive methodologies, as well as *sympoietic*, inventive, and gamified pedagogical practices (Schlemmer, 2018), validated across various educational levels and contexts. This movement gave rise to the concepts of the *symbiote* and learning as crossbreeding and invention, as proposed by Michel Serres, thereby broadening the understanding of inventive cognition based on Kastrup (2015). It has also led to the need to deepen our comprehension of reticular epistemologies, transorganic connective acts, transubstantiation, and atopic inhabitation (Di Felice, 2009, 2012, 2017, 2018); onlife society (Floridi, 2015); hypercomplexity and sympoiesis (Haraway, 2016); as well as hyperobjects (Morton, 2013). These concepts, associated with the challenges of rethinking education in a pandemic and post-pandemic world, have contributed to the conceptual consolidation of what we have come to understand as *OnLIFE*[4] Education.

OnLIFE Education — where "On" refers to connectivity and "LIFE" to life — is characterized as an education that is connected *in* life, one that emerges and develops from the problematizations of contemporary times, the world, and hyperreality. It is a dynamic and evolving concept, situated within a network of relationships between theories, methodologies, and practices that arise from reticular and connective epistemologies (Di Felice, 2012), and from the understanding of digital technologies as technologies of intelligence (Lévy, 1996), which expand, externalize, and transform human cognitive functions. These technologies, as environmental forces (Floridi, 2015), challenge and reframe our understanding of who we are, how we relate to one another, how we perceive the world, and how we interact with it (Schlemmer, 2021; Schlemmer; Moreira, 2020, 2022).

From this perspective, digital technologies and communication networks are no longer understood as mere tools, instruments, resources, supports, or means to be employed in education from a transpositional viewpoint. Rather, they are appropriated within processes of creation and co-creation, as human beings, through their use, invent both themselves and the world, in an

[3] Seymour Papert, a student of Piaget, conceived constructionism as a learning model that operates without deliberate and organized teaching, positioning children as the builders of their intellectual structures, much in the same way that they learn to speak or walk without formal instruction (Papert, 1980, 1994).

[4] The spelling OnLIFE was coined by the International Research Group on Digital Education - GPe-dU UNISINOS/CNPq based on the deepening of theoretical-epistemological concepts, seeking to give more emphasis and thus capitalizing the word LIFE (life), differentiating itself from the term onlife by Floridi (2015).

ecology of intelligences. This scenario challenges us to rethink Bilingual Education from an *OnLIFE* perspective, aiming to break with essentialist views of culture (Megale, 2019a) and to foster the formation of citizens capable of accessing "the multiplicity of discourses that circulate in the world and, in this way, expand their cultural repertoire" (Megale, 2019b, p. 84). Additional languages, circulating through networks via digital technologies as non-human entities, participate in connective acts (Di Felice, 2017) alongside human beings, promoting the communication of multiple discourses. This dynamic characterizes an inter/multicultural formation that fosters the constitution of subjects better prepared to act in superdiverse scenarios (Megale, 2019b; Megale; Liberali, 2016, 2021). This prompts us to ask: in what ways are we appropriating this way of thinking and this language so that present and future generations can be able to understand, record, and engage with the world, with the aim of fostering meaningful social transformations?

The challenge lies in constructing new connective-ecological-ecosystemic pedagogies that enable the development of *OnLIFE* teaching, while also understanding this new educational architecture. In this regard, the following section reports an *OnLIFE* Education experience that inspired this perspective. This practice, which enhances computational thinking, is situated within the urban context and developed within Bilingual Education (English– Portuguese), based on interactions, connections, and appreciation of the German immigration legacy in the city of Novo Hamburgo, RS.

COMPUTATIONAL THINKING IN THE CITY: AN EXPERIENCE OF OnLIFE EDUCATION – METHODOLOGY

The OnLIFE Education experience presented here aims to understand how computational thinking develops and is enhanced through co-generation with the city. We conceive of the city as more than its physical geography: it is a complex, agentic, and communicative entity, inhabited by humans and non-humans who connect and interact through the Internet of Things (IoT), sensorization, wearables, algorithms, and Big Data. From these infoarchitectures emerges a space that transcends the physical-geographical dimension—a cybrid space permeated by digital networks, which transforms the city into information and prompts us to rethink the concept of communication. This cybricity (Schlemmer, 2021) results from the hybridization of a geographically situated physical city with a digital city that expands through connectivity and information, forming transorganic networks (Schlemmer *et al*., 2021).

The experience presented in this article explores the development of computational thinking (CIEB, 2018; Csizmadia *et al.*, 2015; Papert, 1980, 1994; Papert; Solomon, 1971; SBC, 2019; Wing, 2006, 2008, 2016, 2017) in the process of understanding and constructing algorithms, in connection with the cybrid territory of the city and the Code programming platform. From a theoretical-epistemological perspective, this work articulates the hybridization of urban and post-urban spaces (Di Felice, 2009, 2012, 2017, 2018; La Rocca, 2016, 2018); inventive cognition (Kastrup, 2001, 2010, 2015); bilingual education (Megale, 2019a, 2019b; Megale; Liberali, 2016, 2021); and learning projects within the CLIL approach (Coyle, 2008; Souza, 2019). The discussion of this pedagogical practice is framed from the perspective of OnLIFE Education (Schlemmer, 2021; Schlemmer; Moreira, 2020, 2022).

This is a qualitative study, developed through the cartographic method of intervention research, as proposed by Passos, Kastrup, and Escóssia (2015), Passos, Kastrup, and Tedesco (2016), and Kastrup (2019). Unlike other research methods, in which the researcher remains distant and seeks to isolate the object of study, cartography involves the researcher inhabiting the territory under investigation. Rather than collecting data, cartography focuses on data production, analysis, and intervention. Research instruments included photographic records, audio and video recordings and transcriptions, interviews, and field diaries. Cartography (Kastrup, 2019) is guided by clues rather than predefined rules, as the unfolding of processes precludes the establishment of all

methodological procedures in advance. The functioning of attention is a key element in the training of the researcher-cartographer, defined as both open and focused, and structured around four movements: tracking, touching, landing, and attentive recognition.

The Cartographic Method of Intervention Research, in addition to being adopted by GPedU UNISINOS/CNPq as a research method, has been studied and adapted to compose methodologies and to guide the development of pedagogical practices that prioritize the monitoring of learning pathways (Schlemmer; Lopes, 2016). In conjunction with cartography, there is Content and Language Integrated Learning (CLIL) (Coyle, 2008; Souza, 2019). This approach refers to forms of bilingual education in which the additional language serves as the medium for teaching and learning various areas of knowledge, based on the principles of cognition, community, content and communication (Mehisto; Marsh; Frigols, 2008), thus fostering the development of bilingualism and multilingualism. It is anchored in the content-language-skills triad and, as highlighted by Souza (2019), promotes interdisciplinarity between common themes and curricular components while supporting the development of opportunities for reflection on learning and its processes.

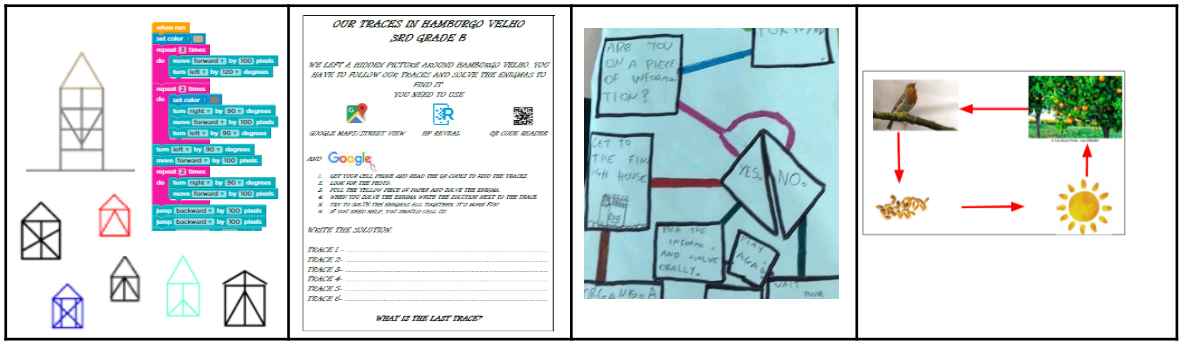
The territory in which the study was conducted comprised basic education, specifically two classes of Elementary School I. It included 39 students, aged 8 to 9, enrolled in a bilingual (Portuguese-English) school in the city of Novo Hamburgo, Rio Grande do Sul, Brazil, between 2019 and 2022. The school is located in the Historic Center of Hamburgo Velho (Old Hamburg) and was the first school founded in the city, in 1832, by German immigrants. As such, part of its heritage and buildings are located within a historical preservation zone and were involved in the celebrations marking the 200th anniversary of German immigration in Brazil.

The curriculum includes a Programming component based on the Code platform (code.org), and studies in the Human Sciences during these school years focus on the city, as established by the BNCC (Brasil, 2017). These studies address memory spaces, social and cultural diversity, and the development of geographic, historical, and spatial analyses of perceived, conceived, and lived spaces. They also encompass cartographic languages, various textual genres, and digital technologies.

In the OnLIFE experience developed, the four movements of the cartographer's attention unfolded through: the exploration of the Historic Center (tracking); the elements that captured attention during these experiences (touching); the networks of forces and connections that emerged as clues for the development of computational thinking (landing); and the CLIL learning projects, which enhanced the construction of algorithms (attentive recognition). The various experiences within the cybrid space of the city gave rise to computational activity, paving the way for understanding how to produce algorithms by thinking through procedures (Papert, 1980, 1994; Papert; Solomon, 1971). These algorithms were constructed through the lived experiences in this territory and involved, as shown in the table below, the following areas and languages:

Table 1 – Algorithms in the city

Fachwerk Algorithm	**Traces in Old Hamburg Algorithm**	**Gamebook Algorithm**	**Nature Algorithm**
Programming of half-timbered houses (architecture of the Historic Center)	Construction of a gamified route exploring the history of the Historic Center	Creation of a gamebook inspired by experiences in the city	Modeling of the recursive relationship between frugivorous birds and trees in the park
Block Language	Narrative	Flowchart	Flowchart



Source: Created by the authors.

The *Traces in Old Hamburg* algorithm (Menezes; Schlemmer; La Roca, 2021) was constructed in text form with the aim of developing a hybrid and gamified route through physical and digital spaces, incorporating puzzles and clues about the history of the historic neighborhood. The *Gamebook* algorithm (Menezes; La Rocca; Schlemmer, 2023) supported the creation of gamified stories invented by the students. The *Nature* algorithm (Menezes; Schlemmer, 2022) emerged from experiences during the Covid-19 pandemic in 2020, when the city's space was further reconfigured using digital platforms, including Google Earth.

The *Fachwerk* algorithm (meaning *half-timbered* in German), the focus of this article, involved the construction—using English—of a block-based algorithm on the Code programming platform, designed to produce drawings of houses in the half-timbered architectural style characteristic of the city's Historic Center. The platform's "Learning Arts with Code" section provided an open programming space that enabled students to create their own drawings using a limited set of commands. These commands specified movements such as *move forward/backward by ... pixels*, *turn right/left by ... degrees*, and *jump forward/backward by ... pixels*. For forward or backward movements, students could choose any number of pixels; however, in relation to turning, the platform offered a predefined set of available degrees. This limitation led to challenges, as in certain cases none of the available degree values were sufficient for a given turn. The analysis of this experience will be presented and discussed below.

CODING THE FACHWERK - ANALYSIS

The analysis of the *Coding the Fachwerk* device's development focuses on students' understanding of algorithms. This analysis unfolds along four key axes: (a) the hybridization of urban and post-urban spaces; (b) the creation of an inventive and bilingual pathway; (c) the adoption of the principle of mathetics; and (d) the incorporation of the OnLIFE Education perspective.

a) On the hybridization of urban and post-urban spaces:

During the inhabitation of the research area, computational activity was observed as occurring *in flux*, facilitating the construction of an understanding of algorithms through the hybridization of physical-geographical and digital spaces. This experience enabled diverse ways of engaging with the meaning of inhabitation. The *Old Hamburg* neighborhood—the primary setting for the experiments—sparked curiosity around the preservation of historical and cultural heritage, its architecture, biodiversity, long-time residents, and the arrival of the first German immigrants, among other elements. The interplay between physical and digital environments fostered the development of computational thinking through the co-engineering of human and non-human entities—such as Germanic architecture, local history, housing, and programming

technologies—that constitute these territories. This process expanded and redefined the understanding of the city through a more ecosystemic lens.

Through these processes, programming activities established connections between computational thinking, the cybricity, and the students themselves, giving rise to computational activity understood as the capacity to think procedurally and to debug in a reconstructive, inventive, and relational manner. As one student remarked: *"We coded in the city; we didn't just stay at the computer"* (Student 1), illustrating the expansion of the platform's digital space into the urban territory. The algorithms developed emerged directly from these spatial experiences, enhancing the evolution of computational thinking, particularly in terms of constructing procedures and subprocedures within algorithm design.

b) On the creation of an inventive and bilingual journey:

This understanding was shaped through experiences of problematization (Kastrup, 2001, 2010, 2015), situated within the context of the cybricity and expanding the notion of cognition as an inventive process, oriented toward the emergence of new and unpredictable problems. In this sense, inventive learning encourages reflection on the present, a world in constant transformation—conceiving learning as a process of becoming and production. The experience took shape as a process of becoming, emerging from problematizations that led to bugs and breakdowns within the co-emergence of human and non-human entities. This encounter with the unthinkable—with that which compels thought—disrupted linearity and challenged the idea of simply following pre-established rules or outcomes.

Cognition expanded through invention, as it resisted the confinement of knowledge within rigid curricular structures or age-related expectations. A telling example emerged when students engaged with a mathematical concept not typically expected at the third-grade level: distinguishing between right and non-right angles in polygonal shapes (Brasil, 2017). Their embodied experiences on neighborhood streets, visits to museums, and research into the half-timbered construction technique fostered an understanding of architectural logic where the concept of angles is central. Faced with a challenge not yet formally introduced, students actively explored and interpreted it, revealing how age-based restrictions often prevent children from investigating, learning, producing, and producing themselves.

As the research unfolded, students became aware of their own development in the English language, as the activities were conducted predominantly in this additional language, including the programming itself. The integration of disciplinary knowledge and language—CLIL (Mehisto; Marsh; Frigols, 2008)—pointed toward a more ecological approach to learning. This, in Morin's (2015a, 2015b) view, entails fluid, interconnected, and non-compartmentalized ways of thinking, teaching, and learning.

Guided by Papert's (1980) principle of *mathetics*, students were encouraged to search, investigate, and expand their lexical repertoire, engaging with meanings grounded in lived experience. As one participant noted: *"I began to understand the algorithm better in English than in Portuguese"* (Student 2), highlighting how the development of additional language and computational logic emerged co-emergently. According to Megale (2019a, 2019b), this multidimensional development of English and Portuguese becomes evident in the expansion of students' lexical repertoire, their ability to construct, interpret, and explain algorithms, and even in the emergence of a third language—German—linked to the cultural legacy of immigration. Additionally, students developed a computational language capable of expressing their thought processes and interacting with the computer. As Papert (1980, p. 18) states, *"the computer can be a mathematical interlocutor or a language interlocutor."* In this experience, students learned to build algorithms using English as a medium of communication, appropriating the language while drawing on the Germanic cultural heritage embedded in their local context.

For García (2009), it is essential to view the linguistic repertoire as dynamic, situated in the relationships between languages, and constitutive of subjects capable of navigating across languages and cultures. Thus, programming the half-timbered houses enabled students to engage in a lived, experiential process—not merely the processing of information—marked by problematizations, bugs, and embodied encounters. These experiences led to the production of concrete artifacts, such as algorithms inspired by half-timbered architecture, the expansion of linguistic and computational knowledge, and the construction of a sense of belonging to the city—aligned with an ecological vision of what (and who) inhabits this space.

c) On the principle of mathetics:

The journey through the city awakened the students' curiosity and desire to explore the architecture of half-timbered houses. This initial interest evolved into a meaningful programming activity in which students recreated the design of these houses, generating a sense of pride and empowerment. Through this engagement, students encountered the history of German immigration and researched the logic behind this architectural style, simultaneously learning elements of geometry and history. These buildings formed the original settlement of *Hamburgerberg*, the precursor of the present-day city.

Rooted in Papert's constructionism (Papert, 1980, 1994; Papert; Solomon, 1971), mathetics is the art of learning—an approach that fosters continuity, agency, and cultural resonance. Drawing on *Turtle Geometry* (Papert, 1980), programming took on new significance, moving beyond a mere 'exercise' but as a meaningful and contextualized learning experience. When students were challenged with problems involving right and non-right angles—knowledge often beyond their official curriculum—they attributed meaning to these concepts based on their lived experiences in the city. They navigated from the familiar to the unfamiliar, engaging with abstract concepts by connecting them to generic and transferable ideas, such as planning, iterative development, and debugging.

When figuring out how to rotate the turtle to draw a square or triangle, the necessity of providing precise numerical values for rotation became conceptually clear. The skill thus emerged organically, driven by a context of curiosity and active exploration. Papert's (1980, p. 87) mathetic principle —*"Make sense of what is to be learned"*—was fully enacted in this experience.

The figure below presents two examples of student-developed algorithms for half-timbered house designs, alongside moments of interaction between students and researchers. The highlighted sections in red reveal how students applied procedures and subprocedures (e.g., blocks to draw squares and triangles), employed pattern recognition (repetition blocks to draw geometric shapes), encountered bugs, and engaged in debugging. These breakdown experiences are reflected in statements such as: *"I stopped for a while to think"* (Student 3), *"Then I saw that the line of the square was 110"* (Student 4). Each exclamation of *"I did it!!!"* (Student 5) marked a moment of empowerment- *"I wanted to do it"* (Student 6), *"I persisted"* (Student 7), *"I liked what I did"* (Student 8)—expressing satisfaction, pride, and a sense of agency.

Figure 1 – Interaction while programming the Fachwerk algorithm

Source: Created by the authors.

Each code represented a fully original and unique production. Students were not constrained by predetermined timeframes or rigid instructional frameworks; instead, each was encouraged to respect their own pace and learning trajectory. The meaningfulness of the knowledge—rooted in real experiences with the city—and the availability of time for exploration, error analysis, and reflection underscored the significance of **mathetics** as a foundation for rethinking pedagogical practices. It revealed the power of learning processes that emerge from curiosity, context, and autonomy, rather than from imposed structures.

d) On the OnLIFE Education perspective:

The experiences lived in the city—and in cybricity—elicited problematizations grounded in life itself. They challenged existing methodologies and pedagogical practices, promoted the hybridization of times, spaces, technologies, presences, languages, and cultures, and fostered the overcoming of traditional dichotomies (such as subject–object, individual–environment) and fixed centralities (whether teacher, content, or student-centered). These processes also supported the development of interdisciplinary and transversal approaches to computational thinking and problem-solving. Learning projects situated in a bilingual context enabled the integration of languages and areas of knowledge, the articulation of diverse cognitive skills, and the strengthening of relationships between students and their community. The lived experiences were transformed into code—co-emergent with a city of atoms and bits.

Students deepened their understanding of the term *algorithm* by engaging with and inhabiting the historic center, coming to see algorithms as sequences of steps embedded in their daily lives—steps that shape and reconfigure how they live and interact. Interview excerpts reveal this shift: *"The bugs weren't bad; they helped us think about the algorithm"* (Student 9), *"I can have more than one algorithm to get from one place to another in the city, so we can compare and decide which is best"* (Student 10), *"Our life is an algorithm too"* (Student 11), and *"This is the*

code of life" (Student 12). These reflections demonstrate that understanding algorithmic logic—and how it organizes and transforms experience—has ethical, political, and civic implications.

What is the "code of life"? What questions does the present world pose to us? What connects us?

Inhabiting is no longer solely the product of a subject's relationship with a physical territory, but rather the result of multiple communicative practices within an ecological network—comprising humans, data, sensors, languages, cultures, codes, software, algorithms, forests, places, and more. "Code" is not merely a programmed sequence of blocks within a platform; it is a system in which symbols, languages, signs, genetics, data, and meanings circulate. It encompasses communication, identification, and interpretation.

This educational experience enabled students and educators alike to grasp what Schlemmer, Di Felice, and Serra (2020, p. 7) describe as *"a complex and inseparable set of worlds and informational and material combinations. An info-world. A network of networks."* The idea of a "code of life" points to a transformation in our living conditions—and, consequently, in our cultural and linguistic consciousness.

The experiences that emerged throughout the project led to the understanding that computing is a way of living, knowing, and producing realities—a form of doing together. The development of computational thinking in and with the city/cybricity was the result of a cognitive policy attentive to the journey: one that is invented as it is lived.

FINAL CONSIDERATIONS

The connectivity and digitality of networks compel us to recognize that we inhabit an ecosystem that transcends physical, geographic, tangible, and visible space. The anthropocentric and dualistic worldview—one that separates and opposes human and environment, human and technology, human and nature—is challenged by the emergence of a network ecology. This ecology articulates the relationships among individuals, biodiversity, technology, information, and territory, highlighting the ecosystemic nature of contemporary networks, where human and non-human entities coexist in mutual interdependence. As these entities interrelate, they co-emerge and transform one another, revealing that domains once perceived as separate are now digitally connected and in continuous interaction.

Aligned with the objective of this study, we demonstrated how computational thinking emerged and developed *in and with* the cybricity, through the lens of inventive learning. This process enabled the co-emergence of human and non-human entities, situated within the paradigms of Bilingual Education and OnLIFE Education. This journey deepened the understanding of computational thinking while simultaneously enhancing students' skills in an additional language. It also allowed them to engage deeply with the sociocultural dimensions of their city, fostering a sense of belonging, an appreciation for memory and cultural heritage in the Historic Center of Old Hamburg, and a more civic-minded awareness of what—and who—inhabits this shared space.

These movements lead us to conceive education as an integral part of a networked ecosystem, one that challenges traditional models of teaching and learning and demands methodologies that respond to the transformations of contemporary society. There is an urgent need to problematize current cognitive policies and move beyond directive pedagogies grounded in the subject–object binary. Equally urgent is a critical discussion of the platformization of education, here understood as the standardization and massification of teaching centered on content delivery, digital worksheets, and the reduction of students to passive executors. This logic stands in stark contrast to the principles of OnLIFE Education.

In this context, Bilingual Education is called upon to foster civic, intercultural, and humanizing development, recognizing the plural, transformative potential of language. By challenging binary thinking, both Bilingual and OnLIFE Education contribute to the expansion of

students' repertoires and their development as agents of transformation—grounded in respect for linguistic and cultural diversity and a critical understanding of how differences are produced. An education that already operates from a distinct linguistic matrix holds greater potential to connect learners with narratives beyond their own, enabling them to access the multiplicity of discourses circulating in this hyperconnected world. Therefore, Bilingual Education must be understood not merely as language instruction, but as a commitment to the systematic design of multicultural education—capable of forming individuals who can see beyond structural dichotomies.

OnLIFE Education, in turn, proposes a new cognitive policy. It is not about applying, adopting, or adapting existing curricula, but about creating a paradigmatic shift consistent with the realities of current technologies and ways of being. This shift demands the development of pedagogies capable of transforming the ways we inhabit teaching and learning. By transcending dichotomies such as subject–object, individual–environment, online–offline, and physical–digital, OnLIFE Education inaugurates an epistemological turn: teaching and learning become networked practices—networks to be inhabited.

In this study, the understanding of computational thinking as empowered *in and with* the city became possible through the adoption of a cognitive policy attentive to the journey—a journey invented as it is lived.

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