Constructionist Co-Design for the Learning Experience: A Work-in-Progress on Engaging Teachers to Integrate Logic Programming in Primary School

Jorge P. Rodríguez[1,†], Laura A. Cecchi[1,*,†]

[1]Grupo de Investigación en Lenguajes e IA, Facultad de Informática, Universidad Nacional del Comahue, Neuquén, Argentina

Abstract

Interest in integrating Computational Thinking (CT) into primary and secondary education has increased notably in recent years. Alongside CT, Logical Thinking (LT) plays a key role by strengthening students' ability to reason critically, identify valid arguments, and avoid fallacies and contradictions. The Logic Programming(LP) paradigm is underrepresented in both introductory Computer Science (CS) courses and in initiatives aimed at developing children's CT and LT skills.

Supporting the integration of LP, CT and LT at primary school requires that teachers develop a solid understanding of these concepts, along with strategies to effectively incorporate them into their teaching practice.

The co-design process itself is a constructionist learning experience that brings researchers, teachers, and developers collaboratively work hand-in-hand to define roles for building educative inventions, conceptualise a design, build a prototype, analyse it, and re-design a prototype to meet the required educational needs.

In order to meaningfully integrate LP into primary education, we propose a collaborative co-design strategy with primary school teachers. This approach aims to recognise and leverage teachers' situated pedagogical knowledge while introducing core concepts of LT and declarative programming. By working together, the goal is to develop context-sensitive and sustainable teaching resources that fit the realities of the classroom and strengthen teachers' agency in bringing new forms of digital literacy into practice. As part of this initiative, we present a workshop for primary school teachers that puts the co-design framework into action. Finally, we describe four learning experiences created by the participating teachers of the workshop, which highlight connections to various topics within the school curriculum and we share some of their reflections on the co-design process.

Keywords

Constructionist, Co-design, Primary Education, Logic Programming, Logical Thinking

1. Introduction

In recent years, interest in incorporating Computational Thinking (CT) into primary and secondary education has grown significantly [1, 2, 3, 4]. In addition to CT, it is also essential to emphasise the role of Logical Thinking (LT) in K-12 education. By fostering students' abilities to recognise patterns, make inferences, and build structured arguments, logical thinking supports critical thinking by helping students distinguish valid arguments from fallacies and contradictions, thus promoting more rigorous and reflective reasoning in both digital and everyday contexts. In a world increasingly shaped by technologies based on Artificial Intelligence, several studies have raised concerns about the potential cognitive effects of intensive use of such tools, particularly concerning critical thinking [5, 6]. This highlights the need to develop pedagogical strategies that encourage active and reflective engagement with these technologies. In this context, logic and LT emerge as essential tools for fostering critical thinking from the early stages of education.

Logic Programming (LP) is a programming paradigm, knowledge representation framework, and database management approach based on formal logic. This paradigm brings together concepts from computing, logic, and reasoning [7]. In this regard, LP represents a key practice for developing specialised

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*Corresponding author.

†These authors contributed equally.

j.rodrig@fi.uncoma.edu.ar (J. P. Rodríguez); lcecchi@fi.uncoma.edu.ar (L. A. Cecchi)

0000-0002-4697-6477 (J. P. Rodríguez); 0000-0001-5236-6715 (L. A. Cecchi)

knowledge in STEM and non-STEM disciplines and for promoting both computational and logical thinking. Moreover, LP can contribute to the development and organisation of various aspects of human thought, as most of the concepts used in human reasoning can be directly supported within LP [8].

However, the LP paradigm is underrepresented in both introductory Computer Science (CS) courses and in initiatives aimed at developing children's CT and LT skills. Unlike the imperative and object-oriented paradigms that dominate traditional CS curricula, LP offers a distinct approach to problem-solving —based on declaring facts and rules.

Supporting the integration of LP, CT and LT at primary school requires that teachers develop a solid understanding of these concepts, along with strategies to effectively incorporate them into their teaching practice.

Accordingly, numerous professional development programs—particularly teacher training initiatives—have been designed to support educators in incorporating CT and LT into their practice by providing strategies to design materials, develop aligned curricula, and embed these practices within classroom instruction. In cases where these units were mainly conceived and delivered by researchers with limited teacher participation, educators often had little ownership of the process [9, 10]. As a result, these efforts often lacked the elements needed to empower educators, support their continuous learning, and ensure the long-term sustainability of CT practices in the school environment.

Research on technology-supported curricula indicates that the level and nature of adoption are strongly influenced by teachers' perceptions of how well these innovations align with their pedagogical goals, instructional approaches, and expectations for student learning outcomes [11, 12].

Since Papert [13] coined the term, constructionism has transformed approaches to teaching and learning. The co-design process itself is a constructionist learning experience that brings researchers, teachers, and developers collaboratively work hand-in-hand to define roles for building educative inventions, conceptualise a design, build a prototype, analyse it, and re-design a prototype to meet the required educational needs [14, 15, 16]. By applying co-design principles, they can collectively respond to classroom challenges and foster improvements in curriculum, pedagogy, and assessment [17].

In order to meaningfully integrate LP into primary education, we propose a collaborative co-design strategy with primary school teachers. This approach aims to recognise and leverage teachers' situated pedagogical knowledge while introducing core concepts of LT and declarative programming. By working together, the goal is to develop context-sensitive and sustainable teaching resources that fit the realities of the classroom and strengthen teachers' agency in bringing new forms of digital literacy into practice.

As part of this initiative, we present a workshop held in Neuquén, Argentina, for primary school teachers that puts the co-design framework into practice. Finally, we describe four learning experiences created by the participating teachers of the workshop, which highlight connections to various topics within the school curriculum.

This paper is structured as follows. Section 2 outlines the co-design approach for developing LP activities. In Section 3, we describe the teacher training workshop. Section 4 presents illustrative case studies. Section 5 offers teacher reflections on the co-design process; and Section 6 provides concluding remarks and outlines directions for future work.

2. Co-Designing Logic Programming Activities

Constructionist approaches emphasize that learners build knowledge actively through making and designing meaningful artifacts. Papert [13] anticipated the growing importance of computation in STEM disciplines and education, and explored how STEM content could be reconceived through computational representations — laying the foundations for what is now known as Computational Thinking. Jeannette Wing then introduced the expression in her seminal essay [18] as follows: *"computational thinking involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science"(p.33).* Thus CT highlights the need to develop the abilities to understand how to solve problems using CS concepts and being an active participant in a digital society [19]. Alongside CT, Logical Thinking (LT) plays a key role by strengthening students' ability to reason critically, identify valid arguments, and avoid fallacies and contradictions. In the literature there is no consensus regarding how to define logical thinking (LT)[20]. In this article we consider that *LT mainly focuses on the abilities needed to identify entities (e.g. objects, concepts) and relationships between them, and to understand, incorporate and soundly use the rules of logical inference relevant to deriving new, implicit ideas in everyday activities, and to reason about and judiciously choose among different logical formulations of the same problem* [21].

The co-design process itself is a constructionist learning experience, in which teachers are not merely expected to follow prescribed scripts but instead take an active role as professional contributors to educational reforms. In educational research, co-design is referred to as a team-based facilitation process with specified roles for researchers, teachers, and developers to work collaboratively together to build an academic invention, design the prototype, and evaluate the prototype to meet the educational requirements [16, 15]

While there is a growing body of work focused on developing CT and teaching Artificial Intelligence and Programming concepts [22, 9, 1, 23, 24], among others, through imperative approaches, there is still limited research and few materials dedicated to LP in primary education. Existing studies show that teaching programming with imperative languages through co-design approach can yield positive results for fostering CT skills and achieving sustained classroom integration [25, 14]. However, co-designing LP experiences with teachers is essential to broaden the pedagogical toolkit beyond imperative approaches. This not only diversifies the ways students engage with computational concepts but also strengthens logical reasoning by introducing declarative paradigms in ways that are context-sensitive and relevant to everyday teaching practice.

Currently, there is a significant lack of dedicated teaching materials for LP at the primary level. This gap means that resources often need to be developed from scratch. Ideally, these materials should be created or adapted by the teachers themselves, who best understand their students' contexts and learning needs. Co-design empowers teachers to produce situated resources that make abstract LP concepts accessible and engaging for young learners.

Another challenge is that LP does not usually have an explicit place within the existing curriculum for primary schools, where dedicated Computer Science subjects are often absent. Therefore, it is crucial to design LP activities that can be meaningfully integrated into other subject areas, such as mathematics, science, or language arts. This cross-curricular alignment helps ensure that LP can be introduced without displacing other learning goals, while enriching students' logical and computational thinking within familiar domains.

As a pedagogical approach, co-design strongly depends on teachers' active participation in developing instructional resources, which results in the creation of relevant and usable classroom materials [16, 26]. While engaging in the co-design process, teachers learn about LP by actively building and shaping the learning materials themselves. In this phase, teachers and collaborators work together to design and produce teaching resources and activities that bring LP concepts to life through materials that are both singular and deeply situated in the local educational context.

The co-design proposal for training teacher to integrate LP in primary school is based on a gamificated strategy, called *Metagame* [27]. Within this framework, teachers actively co-design a unique game instance tailored to their students' needs. In doing so, they select a relevant curricular topic and craft engaging narratives that shape the clues and challenges students will tackle during the game. In this stage, teachers deepen their own understanding of the fundamentals of LP (constants, variable, facts, queries and rules), equipping themselves with the knowledge needed to guide their students effectively. As part of the co-design process, primary school teachers worked together with a researcher who specializes in LP and its pedagogy.

This approach not only supports the integration of LP into meaningful classroom contexts but also empowers teachers to connect programming concepts with real curriculum content, fostering student motivation through storytelling and problem-solving. Furthermore, when teachers are involved in co-designing curricula, they are more likely to take ownership of the innovation, which is essential for sustaining its adoption over time. [28]

In this direction, co-design becomes a collaborative training process through which primary school teachers build their understanding of LP while actively creating teaching materials. This formation combines hands-on exploration of LP concepts with practical use of educational technologies, such as Blockly Prolog [29] and the metagame approach [27], enabling teachers to experiment, prototype, and adapt resources that are meaningful and situated within their classroom contexts.

3. The Teacher Training Workshop

The Teacher Training Workshop has two main objectives regarding its co-design aspects:

1. to engage teachers in a collaborative design experience that deepens and consolidates their understanding of LP, strengthens their teaching practice, and develops their skills to create meaningful learning activities; and
2. to produce educational experiences for teaching LP that are situated within specific, context-sensitive school settings.

The workshop was scheduled as five biweekly sessions, each three hours long. The teachers organised themselves into groups and joined the research team on our campus to participate in co-design activities. Between sessions, they were expected to work on the design of their educational experiences from their homes.

Groups were expected to create proposals linking LP instruction with topics in the school curriculum. Special emphasis was placed on the selection of topics related to environmental stewardship.

The first week of the workshop was dedicated to logical and computational thinking in primary education. The session focused on the overall structure of a gamified learning experience, emphasising the design of immersive narratives.

Both teachers and researchers participated in the selection of curricular topics and the co-design of narratives. They subsequently analysed them from a pedagogical perspective. Tasks also explored the computational tools available for teaching LP to children, including graphic design platforms, Artificial Intelligence applications, and block-based LP environments.

During the second session, work was done on the co-design of clues or challenges. A clue is a small problem embedded in an educational narrative that allows students to advance in the story of the educational game. The pedagogical objective is to introduce or reinforce concepts of LP, especially in Prolog.

In the third session, the developed clues were reviewed, focusing on two aspects:

1. identifying and redesigning the clues that model relationships and simple queries with and without variables;
2. working on the didactic structure of the clue's formulation.

In the fourth session, clues involving rules and conjunctive queries were redesigned. First, the structure and pedagogical formulation of each clue, its presentation, and its connection to LP concepts were reviewed. Then, participants worked on coding them in Prolog.

During the final session, both teachers and researchers took on the role of primary school students, engaging with the educational activities they had designed during the workshop. They subsequently analysed and reviewed the activities from a didactic and disciplinary perspective to propose improvements and identify and highlight consistent aspects in each design.

The entire Teacher Training workshop consisted of co-design, with moments of co-production, review, reflection, and group feedback. Researchers joined the groups as facilitators, actively participating in the collaborative design process. The workshop's co-design component sought to empower teachers through the collaborative creation of resources that deepen their understanding of LP and its practical application, while also producing contextually relevant learning proposals embedded in real educational settings.

At the end of each session, the groups of teachers and researchers exchanged insights on the productions and formulated feedback recommendations. These developed learning experiences are

Figure 1: Primary school teachers and the facilitator working together during the LP co-design workshop.

planned to be implemented in the participating schools, with the aim of gathering evidence and conducting a new cycle of feedback and refinement to further improve the proposals.

4. Case Studies

Eight primary school teachers from urban public schools in Neuquén, Argentina, participated in the workshop, along with two members of our research and development team who specialise in Artificial Intelligence, Computer Science education, and curriculum design. The participants were organised into four teams, each tasked with designing situated learning experiences. Figure 1 illustrates, the participating teachers collaborated closely with the university professor throughout the workshop.

Some of the participating teachers have collaborated with members of our team over the past two years to implement educational experiences teaching LP to children in their schools.; however, none had previously participated in the design of educational experiences. Their previous experience teaching Computer Science and proficiency with computational tools are at a beginner level. This group completed a preliminary course on fundamental LP concepts, consisting of four sessions, each lasting three hours.

Regarding the institutional context, their schools do not have a dedicated curriculum for Computer Science; nevertheless, they have sufficient ICT resources and staff to support the implementation of the proposed learning experiences.

The four learning experiences below, created by the participating teachers, illustrate different instances of *Metagame* for teaching LP in primary schools, highlighting connections to various topics within the school curriculum. To describe these experiences, we integrate a brief overview of each experience and its creators, our observations, and the feedback provided by the teachers at the conclusion of the workshop.

Guardiantes del Tiempo Jurásico (Jurassic Time Guardians): Marina Pavón, Susana Ibarra, and Carolina Huentenao are primary school teachers. They have more than six years of teaching experience and currently work at Primary School 103, a public school located in the eastern part of Neuquén.

They collaborated on the educational experience “Playing Detectives,” carried out at their school in October 2024. The objective of the experience was to introduce children to fundamental concepts of LP. Since then, they have worked closely together to integrate LP into their teaching practices. Although they have no prior experience designing specific activities for teaching LP, they bring extensive expertise in primary education and possess in-depth knowledge of the school context in which this experience will be implemented.

During the co-design workshop, Marina, Susana, and Carolina worked alongside two researchers to design an activity that integrates LP with the study of dinosaurs and their existence across geological eras. Dinosaurs are an engaging curricular topic for teaching across diverse areas of science and history. Their activity proposes a narrative in which children are challenged to correct a strange anomaly that has caused historical data about dinosaurs to begin to disappear. The "Conospiral," a time machine that humanity has developed for time travel, has begun to collapse, and some dinosaur species are appearing in the wrong eras.

Regarding LP concepts, in this activity, children must solve challenges that involve formulating facts, rules, and queries with and without variables. For example, the first challenges require the formulation of facts, which are then used to construct data that model relationships about the geological eras in which different living beings emerged and major landforms were formed.

Archivo Tierra Viva (Living Earth Archive): Gabriela Fincheira, Mariela Echandia, and Pamela Leiva teach in public and private primary schools in the city of Neuquén. They teach primary school classes for children ages six to eight and believe it is absolutely possible and beneficial for children as young as eight to learn logic programming. *"From the most basic approach of learning to respect these rules and consequences, I believe that the rest of the specific content to be addressed can be addressed through logic programming, as another resource within teaching plans."* (Pamela)

They worked with the research team a year before participating in the workshop, collaborating on the development of educational experiences designed by the research team.

During the workshop, Gabriela, Mariela, and Pamela designed a new activity to teach LP to their students, working alongside two members of our research team. The activity focuses on recognising critical environmental issues and their impacts on the ecosystem and the planet.

In this activity, students must model relationships to represent that deforestation destroys forests and affects the ecosystem; mega-mining pollutes soil and water; fracking contaminates groundwater; the massive use of fossil fuels damages the air, water, and climate; and the irresponsible consumption of goods and services depletes natural resources and generates pollution. They are then asked to pose queries such as: What are the specific facts that harm the ecosystem?

Misión Verde (Green Mission): Victoria Delarriba has recently started working as a primary school teacher, teaching children aged 8 to 13 at Primary School 153. Before attending the workshop, she took a course on basic LP concepts. She has taken several courses on teaching programming with Scratch. She considered lesson plans for integrating LP with the Amazon rainforest. She identified various industrial activities that affect the ecosystem and have serious consequences for the environment.

Victoria Delarriba believes that LP is possible throughout primary school. *"I believe that a child can perform logic programming activities from the age of 5 because they can solve problems that involve the use of steps and distinguish repeating patterns."* (Victoria)

The activity is based on a narrative starring the Gray Lord, who was hidden for a long time and now appears to damage the Amazon's most valuable natural treasures. Through different challenges, children will have to discover each of the industrial activities promoted by the Gray Lord and discover the potential consequences for the environment.

In this activity, children must create rules in Prolog to assert that trees are essential to the planet because they produce oxygen and regulate the climate. To continue, they must write knowledge-based queries in Prolog to check whether trees produce oxygen or are essential to the planet.

Exploradores Argentinos en Acción (Argentine Explorers in Action): Héctor Pérez has been teaching at Primary School 207 in Neuquén for less than five years. He did not participate in the experiment developed by the research team before participating in the workshop. Héctor believes LP can probably be taught starting at age nine; he believes it's definitely not possible at younger ages.

In the co-design workshop, Héctor prepared an activity for ten-year-old fifth-grade students to learn about and understand various geographical, historical, cultural, and social aspects of Argentina through role-playing and travel simulations.

Begin the activity by introducing students to the idea of becoming explorers of Argentina, using striking images of different landscapes, folk music, and short stories about the country's diversity to spark their curiosity. Form exploration teams, and assign each team a different region of Argentina to explore (Northwest, Northeast, Cuyo, Pampas, Patagonia, etc.).

In this activity, children must design and codify a knowledge base using facts and rules to represent the main characteristics of each region's terrain, climate, flora, and fauna. They then conduct queries using variables to learn about, for example, a region's flora.

5. Teacher Reflections

Some participating teachers shared their perspectives on the co-design process and their experience developing their own LP learning sequences.

One of the teachers described the initial phase as a challenge, acknowledging the discomfort of stepping outside their pedagogical comfort zone to engage with programming content. This initial uncertainty gradually gave way to curiosity and understanding as the workshop progressed. By the final stages, they felt more confident and enthusiastic after refining their initial ideas through dialogue with the researchers and colleagues. This teacher highlighted that the exchange with peers was enriching, clarifying the educational purpose of the designed activity. They noted that the main takeaway was learning how clues and facts must necessarily work hand in hand and that these elements must be clear and concrete. In addition, they emphasised that they learned how to connect natural language with programming language, how to write clear and simple rules and queries using variables, and how to structure clues so that each one generates multiple facts in Prolog. They expressed gratitude for the support provided and noted that they had completed the programming of clues, facts, rules, and queries as part of the experience.

The second teacher reflected that while they felt comfortable with the selected knowledge areas, they initially struggled with LP concepts, experiencing some cognitive discomfort that prompted further reading, consultations with the team, and careful revision of their initial plan. By the end, they felt they had developed new skills and knowledge to strengthen and expand their original proposal. They emphasised how collaboration with colleagues positively influenced their work by allowing them to revisit their ideas and explore alternative ways of planning. The key learnings included organising content logically, preparing clear reports, and recognising core notions such as "facts," "rules," "constants," and "relationships".

The third teacher explained that they already had curricular content in mind for their grade level, which made it easier to choose a suitable topic for the sequence. However, they initially found the fundamental Prolog concepts challenging and unfamiliar, which made the first sessions disorienting. Over time, particularly during this workshop, they began to grasp these new ideas, recognising the need to adapt their thinking to a computational mindset and to embrace technologies and languages that differ from their daily practice. They found listening to peers' questions and reflections highly valuable, shaping their decision to carry out the proposed sequence. They highlighted the importance of broadening their perspective on teaching strategies, recognising the need for teachers to update their practice and incorporate digital tools relevant to contemporary childhoods. They concluded that designing with and through technology is an essential area for further growth.

Overall, the teachers' reflections reveal the transformative potential of the co-design workshop in deepening their understanding of LP and enhancing their teaching practices. Despite initial challenges and uncertainties, their active engagement and collaborative exchange fostered both professional growth and confidence. The process not only equipped them with foundational programming skills but also encouraged them to rethink curricular content and pedagogical strategies in ways that are contextually relevant and meaningful for their students. These insights underscore the importance of participatory approaches in teacher training for the successful integration of innovative computational concepts in primary education.

6. Conclusions

This work highlights the potential of a constructionist co-design approach to bring LP into primary education in a way that is meaningful, situated, and sustainable. By actively involving teachers in the collaborative design and production of context-sensitive learning experiences, this initiative not only strengthens their understanding of LP concepts but also empowers them as co-creators of innovative curricular materials tailored to their local realities.

Through this co-design process, teachers become key agents of change, building the skills and confidence to embed LP within diverse areas of the primary school curriculum. By connecting LP with themes such as environmental stewardship, history, and regional identity, these experiences demonstrate how computational and logical thinking can enrich interdisciplinary learning while respecting the unique characteristics of each classroom.

Teachers' reflections highlight how the co-design process enhanced their understanding of LP and supported the development of contextually relevant teaching practices, demonstrating the value of collaborative and participatory teacher training.

Moving forward, the next phase will focus on implementing the designed activities in real school settings, gathering evidence, and initiating new cycles of reflection and refinement. This ongoing process aims to strengthen teacher agency, ensure the adaptability of LP teaching practices, and contribute to broader discussions about integrating computational and logical thinking into early education in ways that are locally relevant and pedagogically sound.

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Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT in order to: translate text and, grammar and spelling check. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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