Leaving the Field: Working with Teachers to Integrate Computational Thinking in Mixed-Visual Ability Classrooms Activities

Filipa Rocha
LASIGE, Faculdade de Ciências
ITI/LARSyS, Instituto Superior
Técnico, Universidade de Lisboa
Lisbon, Portugal
fgrocha@fciencias.ulisboa.pt

Beatriz Nogueira
LASIGE, Faculdade de Ciências,
Universidade de Lisboa
Lisbon, Portugal

Isabel Neto
LASIGE, Faculdade de Ciências,
Universidade de Lisboa
Lisbon, Portugal

Tiago Guerreiro
LASIGE, Faculdade de Ciências,
Universidade de Lisboa
Lisbon, Portugal
tjvg@di.fc.ul.pt

Hugo Nicolau
ITI/LARSyS, Instituto Superior
Técnico, Universidade de Lisboa
Lisbon, Portugal
hugo.nicolau@tecnico.ulisboa.pt

Figure 1: Teacher-led orchestration during "leaving the field" phase.

Abstract

Following a long-term design research engagement to develop an accessible programming toolkit with teachers and children for mixed-visual ability collaboration in classrooms, we reached a pivotal moment: leaving the field. Although the toolkit proved effective during researcher-supported use, this transition raised a key question: how can researchers responsibly step back while enabling sustainable adoption? To examine this, we moved beyond the design of the tool itself, returning to a partner school to explore a handover strategy through interviews, co-design sessions, and classroom enactments with teachers. This allowed us to investigate the pedagogical needs, organizational constraints, and operational dependencies that shaped teachers' ability to appropriate the toolkit. Our findings show that sustainable integration requires more than accessible technology; it depends on alignment with school practices, curricular demands, and the complexities of mixed-ability classrooms. We contribute empirical and conceptual insights into the challenges of transitioning from researcher-supported to teacher-led use and offer design implications to support teachers' appropriation of inclusive programming toolkits.

CCS Concepts

• **Human-centered computing → Accessibility systems and tools**; **Accessibility technologies**; **Collaborative and social computing systems and tools**.

Keywords

Accessibility, Mixed-Visual Ability, Collaboration, Computational Thinking

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1 Introduction

Over the last five years, we have worked closely with inclusive schools to design and deploy an accessible programming toolkit that supports mixed-visual ability collaborative Computational Thinking activities in classrooms. Through iterative and participatory design, the toolkit became increasingly accessible and engaging for children. Yet these classroom activities also revealed a persistent dependency: successful implementation often relied on researchers' ongoing involvement in orchestration, troubleshooting, material preparation, and activity flow.

As this long-term collaboration matured, we reached a pivotal moment,"leaving the field": the moment when researchers begin to step back from direct involvement and teachers are expected to appropriate the toolkit within everyday classroom practice [42]. This transition raised a critical question for both design and research practice about what can be sustained beyond the research context, particularly in inclusive classrooms.

Prior work in accessible technologies and participatory design has shown that long-term partnerships can lead to more inclusive and effective tools [21, 22, 36]. However, sustained classroom integration depends on whether teachers can autonomously use and adapt the tool to their everyday practices without ongoing researcher involvement [28, 34, 42, 46]. Research in inclusive and multisensory learning further highlights the challenges teachers face when integrating new technologies into already demanding classroom environments. While such tools can support inclusive teaching practices, they can also introduce additional workload, require training, or adaptation to diverse student needs, and create dependencies on external support [22]. Studies have therefore emphasized the importance of involving teachers throughout the design process so that they develop the confidence, skills, and ownership necessary to integrate technologies into their everyday teaching practices [12]. Taken together, this underscores a persistent gap that even when participatory design succeeds in shaping the tool itself, it does not necessarily create the conditions for sustained classroom use.

Integrating Computational Thinking into school contexts is rarely "plug-and-play". Teachers must align activities with curricular constraints, classroom management, assessment practices, and diverse learning needs [46]. In mixed-visual ability classrooms, these challenges are further amplified by the need to design whole-class equitable and accessible activities, manage differentiated support, and manage collaboration between children with and without visual impairments [23, 26, 27, 32, 36]. As a result, appropriation becomes not only a question of accessibility features but also of pedagogy, classroom orchestration, and institutional constraints.

In this paper, we examine teacher appropriation through the lens of a "leaving the field" moment (Fig. 1). Following our long-term collaboration, we returned to a partner school to explore a handover strategy intended to teacher-led use once researchers step back. We worked with three teachers through interviews, co-design sessions, classroom-enactment observations, and post-activity reflections, to analyzed how appropriation unfolded *in situ*. We frame this process as a "leaving the field" moment, shifting from researcher-led interventions to examining classroom practices to teacher-led classroom practice, in order to understand what is required to maximize the chances of long-term adoption.

To guide this process, we sought to answer the following research question: **What are the challenges and opportunities teachers encounter in appropriating the accessible multimodal programming environment in their mixed-visual ability classrooms?**

Our findings show that appropriation is not only a matter of technical accessibility but a socio-technical process that must be supported from the earliest stages of design. Teachers highlighted material and pedagogical needs, such as aligning activities with curricular expectations and managing collaborative dynamics between children with and without visual impairments. These insights reinforce that accessible technology alone is not enough; meaningful integration requires attention to school practices, whole-class accessibility and awareness, and the sociocultural realities of inclusive education. This paper contributions with: (1) an empirical account of the challenges and opportunities teachers encounter when integrating an accessible multimodal programming environment in mixed-visual-ability classrooms; and (2) design implications for appropriable inclusive programming toolkits, outlining what is required for teachers to meaningfully and sustainably integrate such technologies into everyday practice.

2 Related Work

2.1 Inclusive Computational Thinking in Mixed-Visual Ability Classrooms

Learning Computational Thinking at an early age promotes computational literacy and supports the development of cognitive, problem-solving, and social skills [48]. As a result, there has been a growing shift toward integrating multimodal elements into coding kits, creating opportunities for more inclusive learning environments [4, 14, 25, 38]. These systems incorporate multimodal input, auditory, and haptic feedback to make both text-based and block-based programming accessible to children with BLV [6, 7, 31, 44].

Accessible systems have also been designed to support inclusive and collaborative experiences in mixed-visual-ability settings [31, 35, 39, 45]. Many of these adopt tangible approaches that provide physical representations of code, improving traceability, comprehension, and debugging [24, 44]. By grounding programming in manipulable artifacts, these systems enable children with and without visual impairments to collaboratively interact with technology, supporting shared participation across diverse abilities [36, 47].

Within classroom contexts, collaboration plays a central role. It not only supports learning activities but also fosters social development, peer interaction and inclusion [2, 8, 37]. Prior work has explored how to structure collaboration in mixed-visual ability groups, showing that accessibility is not solely an individual concern, but also a part of interaction design and group dynamics [36, 47].

These efforts align with broader goals in inclusive education, which seek to ensure equitable participation for all students in mainstream classrooms. As argued by Ainscow [1] and Sapon-Shevin [40], inclusion requires continuous efforts to remove barriers to participation and challenges traditional models of instruction. In this process, teachers play a central role in shaping how inclusive activities are enacted, adapted, and sustained in practice.

However, integrating Computational Thinking into everyday classroom practice, particularly in mixed-visual ability settings, remains challenging. Teachers must balance aligning activities with curricular requirements, managing diverse needs, and orchestrating collaborative group work within time and resource constraints. These demands place additional pressure on teachers, who often require specific preparation and training to effectively support inclusive Computational Thinking learning in real classroom contexts.

2.2 Co-Design and Teacher Appropriation

The adoption and appropriation of educational technology by teachers are widely recognized as key factors influencing classroom integration. Prior work shows that teachers' beliefs, confidence, and attitudes toward technology shape their willingness to adopt new tools, as well as their ability to integrate them into everyday teaching practices [11, 18]. Beyond access, successful integration depends on whether teachers can meaningfully incorporate technologies into their pedagogical routines, particularly in contexts that require managing complex social and learning dynamics.

Appropriation, understood as the process through which teachers take ownership of and adapt technologies, is central to the sustainability of Computational Thinking interventions. Rather than a one-time decision, appropriation is a dynamic process shaped by professional development, shifts in beliefs, and institutional support [15]. Teachers are more likely to integrate technologies when they feel confident in using them and perceive clear value for student learning. In inclusive classrooms, this process is further complicated by the need to coordinate diverse learning needs, support collaboration, and ensure equitable participation across students with varying abilities. Studies of accessible classroom technologies, such as vSked, illustrate how teachers must continuously orchestrate interactions and adapt tools to support diverse learners, highlighting the ongoing work required for meaningful appropriation [16].

Participatory and co-design approaches have been widely adopted to address these challenges by involving teachers in the development of educational technologies. Such approaches can improve relevance, usability, and teacher buy-in, increasing the likelihood that tools will be adopted beyond the duration of a research project [19, 28]. However, existing work also shows that co-design does not guarantee sustained use. Longitudinal studies of tangible and embodied learning tools, such as Topobo, demonstrate that appropriation unfolds through situated, everyday use rather than through initial design participation alone [30]. Teachers often struggle to appropriate tools independently unless they are supported by adequate resources, adaptable materials, and communities of practice [41, 42]. This highlights a critical gap between designing for participation and designing for sustained, independent use in real classroom settings.

In the context of Computational Thinking education, these challenges are further amplified. While Computational Thinking is increasingly recognized as an essential skill, its integration into classroom practice remains complex. Teachers must align activities with curricular requirements, manage classroom logistics, and orchestrate collaborative learning experiences, all within existing time and resource constraints [17, 20, 22]. In inclusive classrooms, these demands extend to designing activities that support collaboration between students with and without disabilities, requiring differentiation, coordination, and ongoing adaptation [42]. Real-world deployments of educational technologies further show how breakdowns, workarounds, and teacher improvisation emerge once researchers step back, underscoring the complexity of sustaining technology use in authentic settings [9].

External factors such as limited infrastructure, unequal access to devices, and lack of institutional support further constrain what teachers can realistically implement [17]. Even when technologies are available, these constraints can hinder teachers' ability to adapt and sustain their use in ways that support all learners.

Despite extensive research on inclusive education, Computational Thinking integration, and participatory design, much of the literature focuses on the design and evaluation of technologies during periods of active researcher involvement [10]. Less attention has been paid to how teachers appropriate accessible Computational Thinking technologies once this support is reduced or withdrawn [46]. This gap is particularly critical in inclusive classrooms, where teachers must independently orchestrate whole-class participation, manage collaborative dynamics, and ensure accessibility without external support.

This paper builds on this body of work by examining teacher appropriation as a situated process within inclusive Computational Thinking activities, focusing on the challenges and opportunities that emerge when teachers transition from co-design partners to independently using the toolkit in mixed-visual-ability classrooms.

3 Project Context

This study is situated within a research project conducted in partnership with local schools. In our country, the public education system establishes inclusive education as national policy. In practice, this means students with disabilities, including children with blindness or low vision (BLV), attend mainstream classrooms with dedicated support when available [34]. The education system emphasizes school-level responses to diversity and inclusive classroom practices, while facing persistent challenges related to teacher capacity, resource allocation, and implementation support, as highlighted in the OECD review of inclusive education in the country [29].

While this model aims to enable participation, placing children in the same classroom does not, on its own, mean equal participation. Against this backdrop, our collaboration with schools emerged from concerns shared by researchers, teachers, and school leaders about the lack of accessible Computational Thinking tools and activities for students with visual impairments.

Early engagements with IT and inclusive education teachers examined the strengths and limitations of existing programming environments and robotic toys in educational settings. These studies revealed both opportunities and accessibility barriers, motivating the development of an accessible tangible programming environment for children with visual impairments [33, 38]. Students and teachers participated throughout the design process as both evaluators and contributors, helping refine prototypes and activities across successive studies that explored tangible interaction, sound-based feedback, robotic technologies, alternative collaboration strategies, and varied workspace configurations [35, 36]. Across these deployments, findings consistently underscored the importance of multimodal and flexible design for supporting individual access as well as shared participation, mutual awareness, and equitable collaboration in mixed-ability groups [39]. They also showed that accessibility alone was insufficient for meaningful participation: collaborative activities required careful consideration of how children coordinated, communicated, and contributed within mixed-ability groups.

Teachers played a central role in shaping the research trajectory. As the partnership matured, the focus expanded from evaluating individual technologies to integrating Computational Thinking activities into mixed-visual ability classrooms. Longitudinal engagements revealed that teachers were concerned not only with accessibility but also with the practical conditions required for long-term classroom adoption, including facilitation demands, collaboration support, adaptability to evolving classroom needs, and alignment with curricular structures. These concerns increasingly shaped design priorities, drawing attention to flexibility, classroom orchestration, and sustained engagement alongside accessibility requirements.

In the later stages of the project, a recurring challenge became apparent: although the activities supported inclusive participation, they depended heavily on sustained researcher involvement. Researchers facilitated sessions, supported classroom orchestration, adapted activities *in situ*, troubleshot emerging issues, and maintained technical infrastructures. Although teachers expressed strong interest in continuing the activities, it became clear that sustaining them required more than leaving behind artifacts or disseminating research outputs. These experiences led us to frame the challenge of "leaving the field" as a design concern in its own right.

4 Methodology

This study took place in one of our partner schools, a public primary school in the suburbs of a Western European city.

To examine teacher appropriation, we deliberately reduced the level of researcher facilitation compared to earlier studies. Teachers were responsible for introducing and leading the activity, while researchers primarily observed and documented classroom dynamics.

4.1 Participants

We recruited 3 teachers from the partner primary school, 2 main teachers (T1 and T2) and 1 teacher of inclusive education (TIE): T1 is 25 years old with 3 years of teaching experience, and this was the first year teaching an inclusive class, a third-grade of 20 students, including 2 with low vision and 2 with learning difficulties; T2 is 42 years old with 20 years of experience in her second year teaching an inclusive class, a first-grade of 21 students, including 2 blind students, 1 low-vision student, and 2 neurodivergent students; TIE is 62 years old with 37 years of experience in education with over 16 years of experience supporting primary-grade students with BLV, and has been collaborating with our research team since 2020.

4.2 Procedure

We embarked on a process with teachers where we co-designed an inclusive Computational Thinking activity for them to later implement autonomously using the multimodal programming toolkit in their mixed ability classrooms. Unlike earlier stages of this project, focused on iterative development and researcher-supported participatory design, this phase aimed to understand how teachers could meaningfully appropriate the toolkit without ongoing researcher support by grounding and integrating the toolkit in their classroom curriculum. The study followed three phases: (1) Interviews and activity co-design sessions with teachers; (2) In-class implementation of the activity and observation; and (3) a post-survey to capture teachers' perspectives on challenges, opportunities, and conditions for sustainable use.

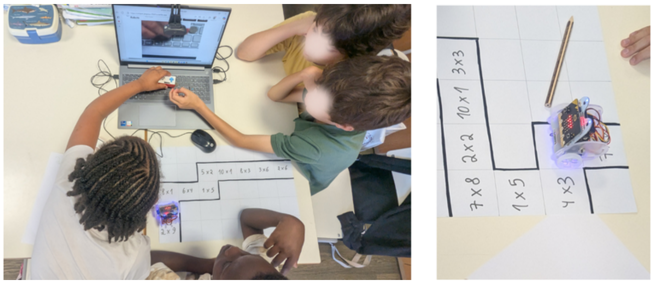
Co-design Interviews The first phase was a one-hour session with two researchers and each main teacher. These sessions combined semi-structured interviews with hands-on exploration of robots (Sony toio[43], micro:bit-based [3], Wonder Dash[49]), tangible programming blocks, and the initial toolkit interface. Teachers were invited to brainstorm multidisciplinary activities that could incorporate the toolkit; discuss how Computational Thinking concepts merge with existing curricular goals; reflect on their role during the activity (group management, time constraints, perceived usability of the toolkit); identify needs to feel confident using the toolkit independently; explore the prototype physically while discussing possible necessary adaptations for their students. These sessions helped shape the activity later deployed in the classroom and revealed early expectations, concerns, and practical constraints.

In-class Activities Following the co-design sessions, we refined the activity and the toolkit for each activity and returned to the school to present the updated activity plan and tool. Teachers reviewed the materials and provided final adjustments before implementation. Each classroom session lasted approximately one hour. Teachers were encouraged to lead the activity while researchers observed, took field notes, and documented classroom dynamics. The sessions focused on how teachers appropriated the activity, how they prepared and organized the classroom, how they facilitated the lesson, and how mixed-visual ability groups collaborated.

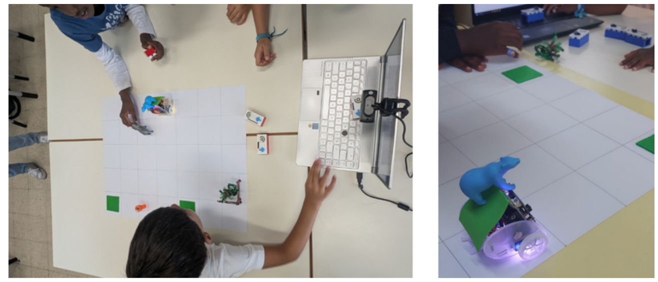
Feedback and Reflection Following the classroom sessions, teachers were invited to complete an anonymous online survey. The survey included 13 open- and closed-ended questions about the perceived value of multidisciplinary robotics and Computational Thinking activities, challenges during implementation, group dynamics, inclusiveness, teacher confidence, and conditions for long-term adoption. Teachers could revisit the online interface while completing the survey. The goal was to capture teachers' perspectives on both the practical and pedagogical dimensions of the intervention, informing future iterations of the toolkit and its integration into everyday teaching practice.

4.3 Programming Toolkit

The toolkit was developed by drawing on accessibility guidelines from prior research [25, 38, 44] and established principles for fostering collaborative learning environments [35, 36, 45]. Rather than being tied to a specific activity, it was designed as a flexible foundation to support different co-designed activities.



(a) Third-grade math activity: a multiplication grid where students program the robot to navigate specific equations.



(b) First-grade animals activity: spatial task using a robot and tactile animal figurines.

Figure 2: Examples of the web-based toolkit using tangible programming blocks with two different robots: (a) a micro:bit-based robot and (b) a SONY toio robot.

At its core, the web-based toolkit connects tangible programming blocks to two different robots, allowing teachers to select between a micro:bit-based robot or a SONY toio robot (Fig.2). The tangible blocks were adapted from existing work leveraging 3D elements, bright colors, and textile markers [7], allowing children of different abilities to program movements (forward, backward, left, and right), and two additional actions based on sound and movement. The camera on the device reads the sequence of blocks, and when children press the *play* block, the instruction set is sent to the robot to execute. Both robots included lights and simple physical features—such as eyes, ears, or a tail—to support accessibility and help children identify their front and back sides. While the robots themselves produced minimal sound, the system provided audio feedback describing their actions (e.g., "I'm moving left"), ensuring that movements were perceivable to all students.

The interaction is structured around a grid that tracks the robot's position and provides environmental feedback. Depending on the activity designed on top of this grid, the system can indicate whether a movement is possible (e.g., preventing the robot from moving forward due to map constraints or activity rules).

This minimal set of functionalities established a shared, low-threshold entry point for participation. It provides a stable base upon which more complex activities can be built, while remaining accessible and adaptable for teachers working in mixed ability classrooms.

4.4 Data Collection & Analysis

We collected audio recordings of the co-design sessions and interviews, along with each researcher's field notes. During the in-class activity, we collected researchers' field notes, photographs of student groups during the activity, and feedback from teachers and children. We also collected the post-survey responses.

Audio recordings were transcribed and analyzed using Reflexive Thematic Analysis [5]. Two researchers independently coded the transcripts and post-survey results using a deductive approach focused on identifying needs, challenges, contextual conditions for appropriation, inclusion and preferences. The coding were iteratively refined into themes through collaborative discussion and the field notes were used to contextualize and deepen interpretation.

4.5 Researcher Positionality

We acknowledge that our experiences and positionality shape how we see and interpret the data. Our team includes researchers from the same country with backgrounds in Human-Computer Interaction, Computer Engineering, and Accessibility. All authors have prior experience studying accessibility and inclusive contexts, and deploying technologies and/or robots in settings with children, which brings practical insight but may also bias interpretation toward design-centric lenses.

While every author made significant and valuable contributions to shaping this work and this paper, their involvement varied throughout the research process. The first author led the research and was embedded in the field. Born and raised in the country of the school, they are a Ph.D. student with a background in teaching technology to children. Over the past five years, they worked closely with inclusive schools, building sustained relationships with inclusive education teachers and students with BLV. This familiarity supported the research during fieldwork, improved accessibility during co-design, and shaped the interpretation of the classroom dynamics and teacher feedback. We recognize that this involvement offers both strengths and limitations. It allowed for richer engagement and contextual sensitivity, but also required ongoing reflection to avoid over-identification with participants or assumptions of shared understanding.

5 Leaving the Field: From Paper to Practice

Our aim was to understand the real-world conditions that shape teachers' ability to appropriate the toolkit and integrate it sustainably into everyday classroom practice. Rather than examining how teachers adapt to the tool, we focused on how the tool and the handover process needed to adapt to their curricular demands, classroom routines, and mixed-ability dynamics. In this section, we present our findings through empirical observations, referred to as **OBS<x>**, and the design insights derived from them, referred to as **DIn<x>**. Together, these illuminate the design elements that supported or hindered appropriation as we prepared to "leave the field".

5.1 Understanding Classroom Realities

The interviews revealed both teachers already engage with Computational Thinking-related concepts, but within curricular, material, and institutional constraints that shape what they perceive as feasible in practice.

T2 explained that Computational Thinking is a national curricular requirement and is *"included in the essential learning material of all the primary education school years"* (T2). In her first-grade class it emerged through mathematics, *"namely problem solving, as well as developing orientation and laterality concepts"*. While describing these activities, it became clear that Computational Thinking was embedded in students' learning and was therefore not perceived as an additional topic, but rather as a curricular objective teachers were expected to support. However, it was rarely associated with technology or programming tools. This disconnect was reinforced by teachers' accounts of how strongly their practice is shaped by the school's adopted textbooks. As T1 noted, *"the textbooks we have don't mention [Scratch]"*, limiting both guidance and justification for introducing programming-based activities. **OBS1**- Both teachers engage with Computational Thinking through existing curricular materials, not through technology or programming tools.

Material constraints further restricted possibilities. Despite a national one-computer-per-student initiative, access remained uneven: *"most of the children in the first-grade do not even have an assigned computer"* (T2). Teachers avoided activities that could exclude students (e.g., *"I'm not going to put just seven with the computer and the others without"* (T2)), instead prioritizing shared use and collaboration. For example, weekly computer sessions to practice their writing skills collaboratively, *"the goal is for everyone to write the entire text"* (T1). **OBS2**- Limited access to material and the need to ensure fairness shaped what teachers considered viable to implement.

Collaboration was a central pedagogical value for both teachers. They emphasized small-group work as a way to promote both learning and inclusion, *"for them to feel integrated and not isolated"* (T2), and to develop social skills such as respect and cooperation. They also leveraged multidisciplinary activities to support creativity and transferable skills. As T1 explained, *"I try to find activities that stray a bit from the curriculum and give them freedom to express themselves in other ways"*. Robotics and programming were seen as motivating when embedded within existing subjects, *"a challenge... they are consolidating without realizing it"*. **OBS3**- Teachers value collaborative, multidisciplinary activities and see potential in robotics when aligned with curricular goals.

However, this enthusiasm was tempered by the realities of their workload and the complexity of the classroom. Teachers managed significant differentiation (e.g., *"I have to plan for two blind students, one low-vision student, two neurodivergent students... and three who are still learning to read"*(T2)) while relying on improvised accessible materials (e.g., bottle caps, everyday objects). As T1 noted, *"the curriculum is very extensive"* and *"it's a very agitated class"*, reminding us that the activity should fit into existing routines and support the diverse learners in their classrooms. **OBS4**- Teachers' workload and classroom differentiation demands make preparation-heavy technological activities unrealistic.

Overall, these observations highlight that both teachers operate within tightly constrained environments, where curriculum, resources, and workload shape not only what is possible but also what is perceived as appropriate to implement. **DIn1**- Integrating new tools requires curricular anchoring and minimal preparation load. **DIn2**- Fairness and equitable participation must be treated as a core design requirement, including accessible materials for students with BLV.

5.2 Co-Designing Within Classroom Constraints

During co-design, the teachers translated these constraints into concrete activities, aligning the toolkit with their pedagogical goals while negotiating feasibility. Our role shifted to facilitating this process, encouraging them to imagine beyond existing constraints, and refining ideas together.

After a brief demonstration of the robots and interface, both teachers had the opportunity to explor how the toolkit could fit their practice, with particular attention to accessibility for students with BLV.

5.2.1 Navigating Math in the Third Grade. T1 proposed a grid-based activity where students programmed the robot while solving mathematical operations embedded in each cell. The initial idea involved comparing paths, *"calculate the distances and see which one was more, which one was less"*. However, this raised concerns about fairness while comparing different results, leading to a revised design in which different paths would yield the same total: *"if both groups do it right, they will get the same value"*. This structure enabled comparison based on the path rather than the outcome, supporting reasoning and debugging. As T1 described, it was *"a fun way to train math"*, as students could retrace their steps to identify errors. **OBS5**- Activities designed activities considering fairness across groups.

To maintain a collaborative group dynamic, the activity was designed for small groups, encouraging collaboration and shared decision-making. T1 also refined interaction details, for example, whether the robot should move the number of squares corresponding to each multiplication result, or whether students should move cell-by-cell and solve the operations along the way. T1 favored the latter for students to perform *"different operations"* in each cell and *"move on, if they answered"* correctly. **OBS6**- The teacher sought activity structures that reinforced curricular content.

Classroom orchestration considerations—number of students, group size, robot availability, and computer distribution—were treated as core design elements rather than afterthoughts. Designing for parallel group work, in particular, was seen as essential for making the activity feasible within the classroom. T1 also emphasized the need to minimize preparation overhead, explaining that *"otherwise I won't have time to prepare it"*. She explicitly requested automated generation of operations *"like chat[GPT] (...) just ask the program to make up the sums"*, to avoid the burden of manually creating the activity materials. Her rationale was clear, the excessive preparation would ultimately lead to the toolkit being *"put aside"* due to existing workload demands. **OBS7**- The teacher preferred small groups working in parallel to manage workflow.

OBS8- The teacher requires simple low-setup tools to not add to their workload.

5.2.2 Connecting Animals. T2 designed a multidisciplinary activity integrating environmental studies and mathematics. Students would program the robot to navigate toward correct answers (e.g., food, habitat, reproduction), reinforcing curriculum topics through interaction. For example, a map could include different food items, such as *"leaves, a steak"*, prompting children to guide the robot based on their assigned animal.

The activity followed a station-based structure, with groups rotating across different challenges, *"it's not work, it's a challenge.. they are consolidating without realizing"*. Maintaining group work was essential for T2, who emphasized that collaboration was already a central value in her classroom. As she explained, *"they will have to work in cooperation [...] reach consensus[...] working on values, respect for others, and following rules"*. **OBS9**- The teacher relied on station-based and collaborative structures to support inclusion and engagement.

Accessibility and simplicity strongly shaped the activity design. T2 favored printed maps, tactile elements, and physical objects, drawing on her existing classroom practices where ongoing differentiation requires materials that are simple, adaptable, and easy to modify. As she explained, *"I'm taking the simple approach of paper so it doesn't have to be too complicated"* (T2). She proposed using additional laminated grids for planning, allowing students to first sketch paths before programming: *"it's much simpler conceptually to think and execute"*. T2 also emphasized the importance of tactile representations (e.g., animal miniatures) to support children with BLV. As she noted, even *"a small figurine helps them understand the animal"* (T2). These considerations highlight how accessibility in inclusive classrooms extends beyond digital interfaces and depends on the availability of tactile, low-complexity materials that the teacher can readily integrate into their existing routines. **OBS10**- The teacher emphasized the need to have accessible, simple, tactile materials to support all students.

Unlike T1, T2 did not request changes to the toolkit itself but asked for time to explore it independently before classroom use. **OBS11**- The teacher required dedicated familiarization time to feel confident using the toolkit autonomously.

From these observations, we can derive: **DIn3**- Simple, low-setup and familiarization time are essential for sustainable integration. **DIn4**- Classroom orchestration structures (parallel group work, stations-based flow) must be built into activity design.

5.3 Enacting the Activities in Practice

Classroom enactments provided insight into how the activities functioned in practice, exposing the limits of teacher autonomy and revealing the hidden labor previously carried by researchers.

5.3.1 Third-Grade Session. T1 handled material distribution and organized the class into small groups, including two mixed-visual ability groups, each with a robot and map enabling parallel work. Students approached the activity competitively and collaboratively, adopting roles and jointly deciding actions. The teacher was able to move around between groups supporting them in the math operations.

Students framed the activity as a competition and even asked to remove the multiplication table hanging on the wall to avoid *"cheating"*. Groups adopted different strategies, including taking turns, and role assignment (e.g., placing blocks, writing, pressing the play command) with no teacher orientation. The system and the robot provided feedback such as *"I'm moving to the left"* or *I can't go this way"*, enabling students to correct mistakes before advancing to the next cell, so debugging moments emerged organically and were solved within groups or they would call out the teacher. **OBS12**- The toolkit child-facing feedback supported group autonomy, reducing the need for teacher-guided moments.

Accessibility limitations emerged due to written operations on the maps, restricting independent participation for BLV students and needing more teacher support. **OBS13**- Inaccessible physical materials shifted additional support demands onto the teacher, limiting group autonomy.

T1 observed that groups collaborated effectively, remained engaged throughout, and that the activity aligned well with her pedagogical goals. She noted that it made *"classes more dynamic"*. Overall, the co-designed structure supported both classroom logistics and students' mathematical reasoning, collaboration, and debugging.

However, this success came with limitations. T1 still relied on researchers for technical troubleshooting, indicating partial—not full—autonomy. Time constraints also posed challenges, as a significant portion of the session was spent by the teacher setting up materials and configuring equipment. Additional sessions would likely have enabled deeper engagement. **OBS14**- The teacher managed pedagogy well but continued to rely on researchers for technical troubleshooting. **OBS15**- Setup and configuration consumed substantial class time, limiting depth of engagement.

5.3.2 First-Grade Session. The first-grade session followed the station-based structure co-designed with T2 with groups rotating across tasks, including one mixed-visual ability group. However, because the activity required multiple materials (computers, maps, robots, animal figures) that were not available at the school, T2 did not feel comfortable setting them up independently and researchers handled setup. **OBS16**- The teacher relied on researchers for setup, limiting her autonomy given the unfamiliarity with the materials.

Students showed high engagement, particularly given the novelty of the robots. However, group dynamics varied, with some uneven participation and moments of distraction requiring teacher intervention. Larger group sizes, driven by logistical constraints, contributed to these dynamics. **OBS17**- Larger and diverse groups demanded substantial teacher support to maintain participation and engagement.

All maps were gridded with relief and included the elements discussed during co-design to represent food, habitats, and reproductive characteristics. However, accessibility remained in one of the maps that relied solely on visual elements, limiting participation for blind students. Miniatures placed on the maps were not always stable, leading to playful interactions that occasionally disrupted the activity. Even with the presence of TIE, the mixed-visual-ability group included more than one BLV student, requiring T2 to remain stationed there to ensure inclusive participation and meaningful participation for both children. **OBS18**- Accessibility constrains disrupted the activity needing continuous teacher attention in the mixed-visual ability group.

T2 reported that the activity supported both collaboration and curricular learning. However, she took a less active facilitation role than anticipated, likely due to limited prior experience with the toolkit. Researchers played a significant role in the setup and support, which may have constrained teacher appropriation.

From both classroom enactment, our observations lead us to derive: **DIn5**- Technical robustness and multimodal accessibility are essential for group autonomy and reducing teacher-guided time. **DIn6**- Setup time must be minimal for sustainable teacher-led integration. **DIn7**- Teachers require prior familiarization and access to materials to confidently take ownership of the activity.

5.4 Post-Study Reflection

The post-study survey largely confirmed what teachers had expressed during the interviews and enacted in their classrooms: both rated the activity as inclusive (Q5, 4/5 and 5/5) and collaborative (Q3, both 5/5), and echoed earlier concerns about group size and accessibility of physical materials for students with BLV (Q4, Q7). Beyond this, teachers surfaced two additional needs that had not been visible during enactment. First, while both teachers indicated they would use the toolkit in their classrooms (Q6, both 4/5), neither expressed unconditional readiness. T2 identified a specific gap in the resources available for autonomous use, requesting *"a manual on how to use the platform (namely what to do in case it freezes)"*. Second, both teachers expressed clear interest in a community where they could request activities and exchange information with other teachers. As T1 noted, such a community *"would facilitate the preparation of robotics lessons"*.

OBS19- Teachers identified troubleshooting documentation as a missing scaffold for autonomous use.

OBS20- Teachers expressed interest in peer communities as infrastructure for sustained practice.

DIn8- Written, referenceable support materials (e.g. troubleshooting guides) are needed to sustain teacher autonomy.

DIn9- Peer support and communities of practice can support teacher appropriation and sustain accessible practice.

5.5 Appropriation as a Situated Process

Across phases, appropriation emerged as situated and ongoing rather than a seamless outcome. Teachers' ability to appropriate the toolkit was shaped less by willingness or skill and more by how well the tool, materials, and handover process aligned with the structural realities of their classrooms.

Interviews revealed the structural foundations of feasibility: curricular anchoring, limited material resources, fairness concerns, and the heavy workload associated with classroom differentiation. These conditions defined what the teachers perceived as appropriate to implement (OBS1–OBS4), leading to early insights about the need for minimal preparation load and equitable participation (DIn1–DIn2).

Co-design sessions translated these constraints into pedagogically grounded activity structures, showing how both teachers adapt tools to their realities rather than the reverse. The teachers redesigned activities to ensure fairness, preferred parallel or station-based group work, and emphasized simple, tactile materials and low preparation demands (OBS5–OBS11). These observations highlighted the importance of low-setup materials, familiarisation time, and orchestration-aware design (DIn3–DIn4).

Classroom enactments exposed the handover gap: the distance between researcher-supported feasibility and teacher-led sustainability. While students engaged collaboratively and the activities aligned with curricular goals, the teachers still relied on researchers for setup, configuration, and troubleshooting (OBS12–OBS18). Accessibility limitations in physical materials further increased teacher burden, particularly in mixed-visual-ability groups. These enactments underscored the need for technical robustness, multimodal feedback, and drastically reduced setup time (DIn5–DIn6), as well as the importance of prior familiarization and material availability for teachers to confidently take ownership (DIn7-DIn8).

Taken together, these findings show that appropriation is not a single moment of adoption but a situated negotiation between teachers' pedagogical intentions, classroom constraints, and the material and technical properties of the toolkit (Table 1). Designing for appropriation therefore requires attending not only to child-facing interaction but also to the teacher-facing ecosystem.

6 Discussion

This work examined the challenges and opportunities teachers face when appropriating an accessible multimodal programming environment in mixed-visual-ability classrooms. Although the toolkit was iteratively co-designed with teachers over several years, this study focused specifically in the handover phase. Our findings show that while teachers could meaningfully shape the activity during co-design, this did not translate into autonomous use. The handover moment revealed dependencies that remained invisible during researcher-supported phases.

Prior work on appropriation, infrastructuring, and teacher orchestration has shown that co-design does not automatically lead to sustained use, and that researcher scaffolding often masks the labor required for everyday use [28, 42]. In mixed-ability settings, the accessibility-driven demands create dependencies that are not captured in existing appropriation literature. As a result, the moment of handover becomes more fragile and revealing.

We argue that appropriation is not achieved at the moment when researchers step back, but is shaped throughout the design process through the continuous redistribution of work, support, and responsibility. In our study, this support could not be withdrawn: teachers continued to rely on researcher-provided setup, troubleshooting, and material preparation. The fact that autonomy never became viable exposed the extent of the orchestration load and made the *handover gap* visible –the distance between researcher-enabled feasibility and teacher-led sustainability.

In this section, we discuss this contribution by examining (1) the challenges and opportunities that shaped appropriation (OBS1–OBS18), and (2) the implications for designing appropriable inclusive classroom technologies (DIn1–DIn7).

Table 1: Summary of study phases, observations, and design insights.

Phase / method	Focus	Observations	Design insights
Co-design interview	Classroom realities: curriculum, resources, workload, differentiation	**OBS1** CT engaged via curriculum, not tools; **OBS2** material scarcity shapes viability; **OBS3** collaboration is a core pedagogical value; **OBS4** workload limits tech-heavy activities.	**DIn1** Curricular anchoring + minimal prep load. **DIn2** Fairness and BLV accessibility as core requirements.
Co-design interview	Translating constraints into concrete activities	**OBS5** activities designed for fairness; **OBS6** structures reinforce curricular content; **OBS7** parallel small-group work preferred; **OBS8** simple, low-setup tools required; **OBS9** station-based structure supports inclusion; **OBS10** tactile, simple materials for all students; **OBS11** familiarisation time needed.	**DIn3** Low-setup + familiarisation time. **DIn4** Orchestration structures built into activity design.
In-class enactment	Teacher-led implementation; handover gap	**OBS12** child-facing feedback supports group autonomy; **OBS13** inaccessible materials shift load to teacher; **OBS14** teachers rely on researchers for tech; **OBS15** setup consumes class time; **OBS16** setup dependency limits autonomy; **OBS17** larger, diverse groups strain support; **OBS18** accessibility gaps demand continuous attention.	**DIn5** Technical robustness + multimodal accessibility. **DIn6** Minimal setup time. **DIn7** Prior familiarisation + material availability.
Post-study survey	Reflection after enactment	**OBS19** troubleshooting documentation identified as missing scaffold; **OBS20** both teachers expressed interest in peer communities.	**DIn8** Written, referenceable support materials. **DIn9** Peer teacher networks as sustainability infrastructure.

6.1 Challenges: Appropriation as Orchestration Under Constraint

6.1.1 Curricular alignment under structural constraints. Interviews revealed that teachers' decisions were shaped by curriculum alignment, fairness, limited material availability, and the workload of differentiation (OBS1, OBS3, OBS6). These structural conditions defined what teachers perceived as feasible and set early boundaries for appropriation. Activities had to be tightly anchored in curricular goals and assessment expectations to be perceived as legitimate and feasible. Appropriation was therefore constrained not only by teachers' individual confidence [11], but also by curriculum and textbook restrictions. Even when teachers recognized pedagogical value, these external constraints shaped what they considered viable to implement.

6.1.2 Material and orchestration filters. Teachers' decisions were also shaped by classroom orchestration demands and existing workload (OBS2, OBS4, OBS5, OBS7, OBS8, OBS9). During classroom enactments, activities appeared successful, but this success depended on researcher-provided setup, troubleshooting, and real-time scaffolding. Because this labor could not be withdrawn without compromising the activity, teachers never reached a point of autonomous orchestration.

During co-design, teachers adapted activities to their classroom rhythms, preferring parallel or station-based structures and simple, tactile materials that could be managed within their routines. These adaptations highlighted the challenge of orchestrating an inclusive activity that must accommodate diverse sensory needs, ensure equitable participation, and maintain manageable pacing. Teachers consistently sought to reduce preparation load and avoid solutions that introduced additional complexity.

Limited device access and fairness concerns led teachers to avoid activities that could exclude students or require complex rotations. At the same time, heavy differentiation –supporting students with BLV, neurodivergent learners, and children still learning to read– meant that preparation-heavy or fragile setups were quickly deemed unrealistic. Teachers explicitly resisted designs that added to their workload, requesting low-setup tools and automated generation of materials to avoid activities being "put aside".

Orchestration and workload thus acted as filters: if an activity could not fit existing rhythms and constraints, it was unlikely to be appropriated. This aligns with prior work showing that technology integration depends not only on access to tools, but on their fit with teachers' time, cognitive load, and classroom constraints [30, 34].

6.1.3 Accessibility for group autonomy. Classroom enactments exposed the operational dependencies that prevented autonomous use. Students engaged collaboratively and benefited from child-facing feedback, but teachers relied on researchers for setup, configuration, and troubleshooting. Accessibility needs further complicated appropriation by shaping both group autonomy and teacher intervention (OBS10, OBS12, OBS13, OBS17, OBS18).

Teachers emphasized simple, tactile materials and valued child-facing feedback that enabled groups to debug and progress independently. However, inaccessible physical materials –such as printed-only maps– shifted additional support demands onto teachers, especially in mixed-visual ability groups. Larger and more diverse groups also amplified these demands, as teachers had to mediate participation, resolve conflicts, and compensate for accessibility gaps.

These dynamics revealed how accessibility is not only a property of the interface, but a determinant of how much hidden labor teachers must perform to keep inclusive activity flow. Delays in system feedback, inaccessible materials, and group dynamics quickly lead to disengagement or exclusion requiring teachers assistance. Without researcher support, these breakdowns became structural barriers to appropriation.Teachers therefore never reached a point of independent orchestration, making the handover gap explicit.

Together, these challenges show that appropriation is not a single moment of adoption but a situated negotiation between pedagogical intentions, classroom realities, and the material and technical properties of the toolkit. Scaling to new audiences further exposes this fragility. Prior work highlights the difficulties "when aiming for scaling PD initiatives" and the limited support available to teachers who lack familiarity with the full research project [42]. This dynamic was evident in our study, the toolkit had been co-designed over several years with participants including TIE, but was introduced for this study to teachers who had not been part of that long-term trajectory. Although the co-design sessions allowed these new teachers to align the tool with their pedagogical goals and design activities that fit their classroom realities, this alignment did not extend into classroom autonomy. Teachers continued to rely on researchers for setup, troubleshooting, and orchestration during enactment (OBS14, OBS16). This suggests that PD scaling is not only limited by mutual learning gaps between old and new participants, but also by the accumulated infrastructure that longitudinal participants absorb and that new teachers cannot reconstruct within a single design cycle.

6.2 Opportunities: Co-Designing for Pedagogical Alignment and Inclusion

6.2.1 Pedagogical alignment. The curricular constraints that limited appropriation also created an opportunity for pedagogical alignment (OBS1, OBS3, OBS6). The co-design allowed teachers to embed the toolkit within existing subjects, using robots to reinforce mathematical reasoning, environmental studies, and problem-solving while leveraging collaboration. Rather than treating CT as an add-on, teachers positioned it as a way to "consolidate without realizing", integrating robotics as a vehicle for curricular consolidation. This extends prior participatory design work [28, 41] by showing that alignment is not only conceptual, but also temporal and organizational.

6.2.2 Embedding orchestration structures into activity design. Teachers' orchestration strategies –parallel group work, station-based flows, and small collaborative groups– also point to concrete design opportunities (OBS2, OBS4, OBS5, OBS7, OBS8, OBS9). Teachers consistently prioritized simplicity, resisting solutions that introduced additional preparation time or complexity. Embedding group configurations, pacing, and fairness considerations into the activity itself, the toolkit can offload some of the orchestration burden from teachers. This reframes co-design as jointly shaping both content and orchestration logic.

6.2.3 Inclusive and adaptive practices. Classroom enactments revealed substantial diversity in student engagement, ranging from enthusiasm and playful to frustration and sensory overload. These differences highlight the need to design for group autonomy as well as individual access (OBS10, OBS12, OBS13, OBS17, OBS18). Child-facing feedback and tactile materials enabled students to collaborate, debug, and progress with less teacher intervention, suggesting that accessibility features can function as orchestration supports. Conversely, inaccessible or fragile materials increased teacher workload and undermined participation. This points to an opportunity to treat accessibility as a socio-technical property: one that shapes how responsibility is distributed between students, teachers, and the toolkit during classroom activity.

6.3 Design and Research Implications: Toward *Appropriable* Inclusive Classroom Technologies

Our design insights (DIn1–DIn7) suggest that designing for mixed-visual ability classrooms requires moving beyond accessible interfaces toward *appropriable* socio-technical systems that teachers can realistically integrate, adapt, and sustain within everyday classroom practice. Our findings show that appropriation depends not only on accessibility, but also on whether technologies align with teachers' curricular goals, orchestration routines, and workload constraints. Building on this, we propose design considerations for inclusive collaborative technologies that better support sustainable appropriation in real classroom settings.

Curricular and Pedagogical Anchoring (DIn1) Our findings show that appropriation depended on whether teachers could embed activities within existing curricular and pedagogical structures. Rather than treating robotics or programming as standalone activities, teachers positioned them as vehicles for reinforcing mathematical reasoning, environmental studies, and collaborative problem-solving. This aligns with prior work showing that teachers are more likely to adopt and sustain educational technologies when they can connect them to existing learning objectives and curricular requirements, rather than introducing them as additional content areas [17].

To support this process, the toolkit and its supporting resources should facilitate curricular integration through curriculum-linked activity guides, examples of cross-subject applications, and adaptable lesson structures that reduce the effort required for classroom implementation. Curriculum mappings, ready-to-use lesson plans, and subject-specific activity variations can therefore serve not only as pedagogical resources but also as handover mechanisms that support continued use after researcher involvement ends. By embedding pathways for curricular adaptation into the toolkit itself, designers can increase the likelihood that teachers appropriate the technology within their everyday practice and sustain its use over time.

Accessibility as Orchestration Support (DIn2, DIn5) Our findings extend conventional views of accessibility by showing that accessibility features shape not only individual participation but also the distribution of orchestration labor within the classroom. Child-facing multimodal feedback enabled students to debug, coordinate, and progress more autonomously, reducing the need for continuous teacher intervention. Conversely, inaccessible or fragile materials increased teacher mediation, particularly in mixed-visual-ability groups where participation often depended on adapting activities or resolving breakdowns.

Inclusive classroom technologies should therefore treat accessibility as a socio-technical orchestration concern rather than solely an interface property. Designers should consider how accessibility features support not only learners' access to activities but also teachers' ability to manage participation and classroom flow. Designing for accessibility consequently also means designing for sustainable classroom use. Accessibility features that promote student autonomy and peer support can reduce orchestration demands on teachers while supporting more equitable participation across mixed-ability groups. This aligns with prior work demonstrating flexible mechanisms, real-time feedback, and mediation tools embedded in the toolkit can support participation, engagement, and accessibility in collaborative learning environments [36, 39].

Designing for Sustainable Orchestration (DIn3, DIn4, DIn6) Consistent with prior work, our findings show that the success of the co-design session and its classroom enactment would not necessarily translate into sustainable autonomous [30]. In our study, this became particularly evident during the classroom enactment phase that was intended to be teacher-led with minimal researcher involvement but still relied on research support for preparation and troubleshooting.

These findings suggest that appropriation also depends on whether teachers can manage entire activity flows under real classroom constraints. Setup complexity is especially critical, as teachers often consider extensive configuration, perceived technical knowledge, and troubleshooting as additional workload that competes with limited classroom time. Consequently, reducing setup effort can directly increase the likelihood of long-term use.

Educational technologies should support the full lifecycle of classroom enactment by providing structured mechanisms for setup, group organization, pacing, and troubleshooting. As T1 suggested, conversational interfaces similar to ChatGPT may provide a practical and familiar way to set up and manage activities while reducing orchestration demands. By leveraging interaction patterns that teachers already understand, such interfaces may lower the learning curve associated with new technologies and potentially accelerating the path toward sustained use.

Orchestration can also be distributed rather than concentrated in the teacher alone. Prior work, demonstrates how embedding small, asymmetric, low-effort educator roles within activities can support coordination at scale, such as the "control tower" or the "storefront" roles described in [36].

We therefore argue that orchestration support should be explicitly scaffolded from the outset as a design property of both systems and activity structures, enabling teachers to manage classroom activities independently while distributing coordination demands across tools, roles, and interaction design within real classroom constraints.

Supporting Materials for Handover (DIn7-DIn9) We argue that researcher withdrawal should be treated as an inevitable design phase that is considered from the outset, requiring explicit handover strategies, gradual transfer of responsibility, and materials that ensure teachers can independently set up, adapt, and troubleshoot activities. A key barrier to appropriation is the loss of researcher-provided support. To address this, such support should be externalized into durable and reusable resources, including lesson plans, setup guides, troubleshooting documentation, and peer-support infrastructures, such as communities for sharing resources and solutions.

Supporting materials can also include interactive and scenario-based resources that facilitate the creation and adaptation of activities. Building on prior work on mixed-ability collaboration [13, 36], which highlights the role of interdependence and asymmetric roles in supporting group coordination and engagement, these structures can be directly embedded into the system as configurable activity templates. For example, the toolkit can provide pre-configured group activity formats that teachers instantiate by selecting a topic or classroom context and filling in structured parameters (e.g., group size, role distribution, or task type), thereby reducing setup effort while preserving flexibility. In addition, conversational interfaces, as previously discussed, can support setup flows and provide embedded "quick troubleshooting guides" for time-critical classroom situations. These resources should prioritize rapid diagnosis and actionable steps for common issues, reducing disruption during live activities and helping teachers feel continuously supported during enactment. Together, these elements contribute to a layered support ecosystem.

7 Limitations and Future Work

This work is based on a qualitative study conducted with a small number of teachers within a single school context. Which this enabled a deep, situated understanding of appropriation in mixed-visual ability classrooms, but limits the generalizability of our findings since educational systems differ in terms of curriculum structures, resource availability, and support for inclusive education.

Second, the participatory process involved close collaboration between researchers and teachers over an extended period. While this is a strength of the study, it may also have influenced teachers' engagement, expectations, and reliance on researcher support. In particular, the presence of researchers during enactments may have stabilized activities in ways that are difficult to replicate in fully independent settings.

Fourth, the toolkit itself –its current design maturity, material requirements, and accessibility features– may have influenced the orchestration demands observed. Some barriers may stem from the specific configuration of the prototype rather than from appropriation processes more broadly. Future work should explore how different design choices affect teachers' ability to appropriate the tool.

8 Conclusion

This paper investigated teacher appropriation of an accessible multimodal programming environment through the lens of a "leaving the field" moment following a long-term collaborative project. By exploring a handover strategy involving co-design, supported classroom enactment, and gradual researcher withdrawal, we observed how appropriation unfolded as responsibility shifted toward teacher-led practice. While co-design supported the development of accessible and pedagogically meaningful activities, it did not guarantee sustained, independent classroom use.

Across classroom enactments, appropriation was shaped less by interface accessibility than by the broader conditions of teaching practice, including curriculum constraints, classroom orchestration, material preparation, and unequal access to resources. In mixed-visual ability settings, these challenges were amplified by the need to support equitable participation and diverse learner needs.

Our findings show that "leaving the field" is not a procedural endpoint but an ongoing transition that reveals the dependencies underpinning successful deployments. We therefore argue that appropriation is a socio-technical process extending beyond co-design, requiring attention to the infrastructures, responsibilities, and orchestration work that enable inclusive classroom technologies to persist after researchers step back.

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