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► **To cite this version:**

Nathalie Bressa, Susanne Bødker, Clemens Klokmoose, Eva Eriksson. Common Objects for Programming Workshops in Non-Formal Learning Contexts. IFIP Conference on Human-Computer Interaction, Aug 2023, York, United Kingdom. pp.275-296, 10.1007/978-3-031-42280-5_16. hal-04377024

HAL Id: hal-04377024

<https://hal.science/hal-04377024v1>

Submitted on 7 Jan 2024

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Common Objects for Programming Workshops in Non-Formal Learning Contexts

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Fig. 1. Two programming workshops for children and adolescents that we observed: *Workshop 1 Technology Play* and *Workshop 2 Robot Art*.

Abstract. We investigate common objects as material support for programming workshops for children and adolescents in non-formal learning contexts. To this end, we engaged in a one-year participatory design process with a facilitator of programming workshops. Based on observations of workshops and interviews with the facilitator, we mapped out their artifact ecologies to investigate how the multiple artifacts and common objects were orchestrated by the facilitator and then adopted by the participants of the workshops. Building on these findings, we explored the development of a collaborative teaching tool, MicroTinker, through a participatory design process with the facilitator. This paper presents the results of our analyses and shows their constructive use to design technology in a non-formal learning setting.

Keywords: Artifact ecology · non-formal learning · participatory design · programming education.

1 Introduction

Research on learning programming has a long tradition [31]. This research has shifted over the years from a predominantly individualistic and tool-oriented

focus to one that is sociologically and culturally grounded [29]. In line with this, we investigate the social and material structures that constitute a set of programming workshops for children and adolescents in non-formal learning environments, outside of formal education [39]. Such non-formal settings are key for the development of technology skills, such as programming [32]. Early exposure to programming can bring many benefits, increasing children’s interest in computing and promoting their social, emotional, and cognitive development [8,21].

However, current software tools for educational settings are often designed around a laptop programming paradigm that tends to restrict collaboration rather than encourage shifting of roles and sharing of experiences when learning technology skills [47]. Because the availability of tools and the purposes of the learning activity, as set by the facilitator or the participant, affect the intended outcomes, it is important for facilitation to match tools with purpose, space, and characteristics of the participants [36,20]. HCI studies of technology education in non-formal learning contexts typically have a specific single focus, such as factors that impact learning [41], a specific technology like Scratch [35], or a specific context such as a makerspace [49]. The real-world integration between a heterogeneous set of technologies and broader social and cultural concerns within educational technologies is missing [48], except for a few culturally grounded studies of technology use in non-formal learning environments [4].

We present findings from an artifact ecology analysis of non-formal programming workshops for children and adolescents and a participatory design process where we designed a collaborative teaching tool together with a facilitator with life-long experience in technology education. Focusing on multiplicities of artifacts, objects and, purposes [34], we first conducted an artifact ecology analysis based on observations of six programming workshops and interviews with the facilitator. An artifact ecology analysis foregrounds the relationships of artifacts to practices in the context of individuals or groups [34] and has been applied to different contexts such as collaborative writing [33] and volunteer communities [17]. We used these theoretical concepts generatively [7] i.e., analytically, critically, and constructively to make them actionable in a participatory design process over six months with the facilitator whose workshops we had observed. We built a collaborative teaching tool, MicroTinker, focusing on sharing and common objects to support the facilitation of workshops. As a starting point, we used a locally developed software platform, CoTinker, for orchestrating learning activities around programming. We implemented an activity for micro:bit with MicroTinker and explored it in two workshops with teachers and children.

Our findings highlight how an artifact ecology analysis focused on the facilitator’s orchestration and participants’ adoption can help identify both explicit and implicit knowledge about these types of learning environments. Using the insights in the PD process allowed us to formulate situated implications for design and point towards possibilities for remediation of the material support.

2 Background

Non-formal learning takes place outside of formal learning environments, such as schools but within an organizational framing, for instance, in museums, libraries, computer clubs, or maker spaces [39,24]. It is supportive and guided or teacher-led. The workshops we observed and designed for were all set in non-formal learning contexts with some structure in their organization to emphasize learning about programming and technology. In the following, we provide more background specifically on computing and technology support in informal and non-formal learning contexts and work on artifact ecologies and common objects.

2.1 Material Support and Non-Formal Learning Contexts

In non-formal technology education environments, activities are typically constituted of diverse programming and making activities, integrating playfulness and creativity [52]. However, research is still scattered across disciplines, for instance, in education, library science, and computer science [36]. Some studies investigate factors of learning [24] like the role of age and gender [52], while other research focuses on specific learning technology like Scratch [35], a specific context such as makerspaces [49], or specific formats like hackathons and game jams [25]. Studies of the Scratch online programming community [43,45,30,19] expand the focus on tangible construction kits and programming tools to also include more intangible aspects, such as social and cultural dimensions [45].

In non-formal learning contexts factors such as the use of design materials, spaces, and collaborative aspects are important to consider [27,45]. Previous work has covered after-school programs to foster computing and technological literacy [4] investigating the affordances for social interaction with technology [3,22], the development of situated learning practices [4], and socially embodied performance as an important element in children’s programming activities to complement more cognitive foci, such as memory, perception and conceptual understanding [26]. Whereas education around technology and micro-controllers is often set in collaborative group contexts, most software tools available are still designed around a laptop programming paradigm that tends to restrict collaboration rather than encourage shifting of roles and sharing of experiences [47].

Upon this background, we see learning to program in non-formal learning environments as mediated by a variety of artifacts from robots to programming environments, and tools where participants are collaborating and focusing on the objects of their activity [11]. To provide the means to further analyze these material and collaborative aspects, we move on to presenting artifact ecologies and common objects [2,33,17,16,15,34].

2.2 Artifact Ecologies and Common Objects

Human activity is mediated, social, and happening through common objects and artifacts according to the basic principles of activity theoretical HCI [14,11]. Technological objects exist in ecologies with other objects, used by people, not

in singular activities, but together across webs of activities. Human use of particular artifacts and objects happens across activities, configurations of people, applications, and devices, and it is analytically important to embrace such transitions and substitutions [14,15].

Objects are held in *common* through the simple exchange of objects, sharing of objects, and common views of the same object [33]. Such objects are in the making as the object moves from (shared) material to product and they contain and represent for the user an idea of the end product (or intermediate products along the way). It is important to be able to analyze the multiplicity of objects and artifacts [16] and artifact ecology as a concept foregrounds the relationships of artifacts to practices, in the context of individuals or groups of people [34]. Hence, the notion of artifact ecologies allows for examining the multiple interactive artifacts in use and highlights the multiplicity and dynamics of computer-mediated collaborative activity including the interplay between the personal and the shared [33]. It puts emphasis both on the multiplicity of devices through which common objects are accessed and activated, on changing configurations of tools (software and hardware), the settings and contexts in which use happens, and the connected activities; for instance, whether there is a particular, possibly enforced order of things [2].

Artifact ecologies help understand common objects and mediators in the context of other objects and mediators that are used in an activity. As such, the dynamic relationships between artifacts in an ecology may be used to analytically frame developments in how activities are carried out and what meaning each artifact holds in relation to the activity [2]. In the following, we are primarily concerned with how joint learning activity is supported through common objects, mediators, and their dynamics.

3 Process and Method

This paper investigates how artifacts in programming workshops mediate the activities with a focus on shared and common objects using these concepts both analytically and constructively ([6,2]) to design material support.

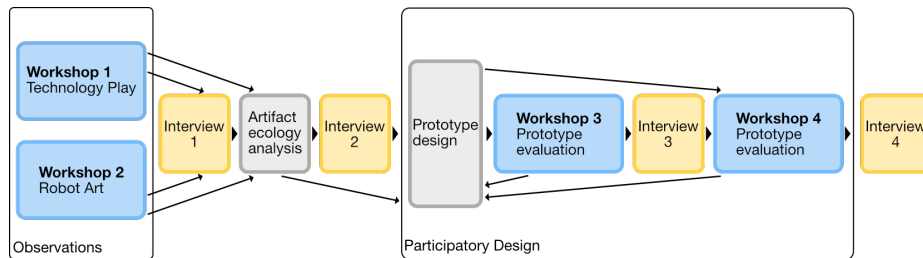


Fig. 2. Overview of the research process from observations to participatory design.

We employed a participatory design approach [13,12] (see Figure 2). First, we collected empirical data from participant observations [51] of two programming workshops in six instances (*Workshop 1 Technology Play* and *Workshop 2 Robot Art*), followed by *Interview1* with the facilitator of the workshops (henceforth referred to as *Facilitator*). Based on this, we conducted an artifact ecology analysis [28], mapping the different workshop activities to investigate the ecologies, technologies, layouts, and the collaboration and sharing between participants.

Based on the findings from the artifact ecology analysis, we interviewed the Facilitator again (*Interview2*), and carried out a participatory design process where we iteratively co-designed, developed, and explored a web-based teaching tool with the Facilitator. We analyzed the design interactively with the finding from the artifact ecology analysis and used and evaluated it in two different workshops (*Workshop 3 Prototype evaluation* and *Workshop 4 Prototype evaluation*). Interwoven with this, we also conducted two additional interviews (*Interview3* and *Interview4*) with the Facilitator.

Our methodological approach is to study the very particular [9] where we engaged with a Facilitator throughout a one-year process. The Facilitator works at the computer science department of a university, has a long career teaching university students, and is the leading educator of high school teachers in the municipality. The Facilitator has developed teaching materials on programmable robots and is organizing various formal, informal, and non-formal learning events for children, such as local maker fairs, programming clubs, and international programming competitions such as the World Programming Olympiad.

3.1 Observations and Workshops

We conducted observations [51] of two different workshops (*Workshop 1 Technology Play* and *Workshop 2 Robot Art*) in six different instances over four months. This included one workshop series (*Workshop 1 Technology Play*) with the same participants consisting of five consecutive events. The workshops were organized by the Facilitator. All workshops were set in a non-formal learning context for children and adolescents (aged 9-21) within the general theme of programming for beginners. The participants were recruited by the Facilitator. All activities were free of charge and provided food and drinks for participants. The participants and their parents were informed of the researchers' presence and the purpose and type of data that we collected. We conducted the observations by attending each of the workshops and collecting field notes without interacting with the participants. We used an observation grid consisting of the dimensions: space and tools, children, facilitators, and procedure. The observation grid served as a reminder to reflect on each of the dimensions as different points of focus. The two workshops studied were:

Workshop 1 Technology Play. This workshop series took place for five consecutive weeks for two hours with nine participants in the evenings in a robotics workshop at a university. The activity targeted girls aged 9-11 and was co-organized by an organization and the university. The participants built a concert

stage with light, music, and moving singers and dancers using LEGO Spike Prime which is a learning tool that enables building with LEGO and programming of motors and sensors with a block-based programming language³. In the first two gatherings, the participants got familiar with LEGO Spike Prime by building walking grasshopper robots in groups of two. In the next three instances, they built stages in wooden cubes. In the last instance, each group presented their stage through a performance.

Workshop 2 Robot Art. This workshop was organized within an IT Camp for girls at a university. Participants, between the ages of 16-21, participated in a range of activities and lectures over a week. The workshop took place in a lecture room with 28 participants for two hours. The theme of the activity was to build a drawing robot with LEGO Spike Prime in groups of three to create an art piece. The drawing robot held a pen and could be programmed to draw different shapes with a block-based programming language. Each group created one art piece that was then presented at the end in an art exhibition.

3.2 Interviews 1-4

We recruited the Facilitator for four semi-structured interviews, conducted by one of the researchers. These interviews were carried out in person, lasted around 45-100 minutes, and were audio recorded and transcribed. The interviews were conducted at different points in the process (see Figure 2). With the interviews, we aimed to better understand the reasoning and motivations of the Facilitator with regard to how workshops were organized, to supplement the observations, and to get insights into the experience with the participatory design process.

3.3 Artifact Ecology Analysis

We conducted an artifact ecology analysis and visual mapping of the observed workshops and coded the interviews and notes from the observations. Visual mappings [28] were done by visually grouping artifacts based on empirical data (see Figure 3). We did a spatial mapping of the room layout for the start and end of the activity, focusing on space, people, tools, and spatial positions. This led to a detailed map of the technologies, materials, and processes.

For the coding of the empirical material, we used notes from observations and transcribed interviews. We developed the codes over multiple iterations and discussed them in meetings among researchers. We then structured the emerging themes into categories, condensed descriptions, and illustrative quotes.

3.4 Prototype Design

We conducted a participatory design (PD) [13] process with the Facilitator that tied into the findings from the artifact ecology analysis. The focus of the design

³ An example of such a workshop: <https://www.youtube.com/watch?v=0YGq7cjs9Xw>

explorations was to scaffold collaboration and knowledge sharing of programming through software. We used our CoTinker platform [38] as a foundation for prototyping which is an experimental platform for exploring collaboration and facilitation in computational thinking-related learning activities. As a starting point, we used our first CoTinker-based prototype [38] designed for a learning activity in high-school biology as a *provotype* [37] because the pedagogical and didactical approach it embodied differed drastically from the one practiced by the Facilitator. Together with the Facilitator, we designed and developed a collaborative teaching tool, *MicroTinker* that integrates micro:bit [1] Micro-controllers such as the micro:bit are increasingly used in classroom settings to teach skills, attitudes, and knowledge around technology [1], and are commonly used in schools in Denmark. The iterative PD process ran as a series of bi-weekly design sessions between the Facilitator, researchers, and developers of CoTinker, as well as ad-hoc meetings between the Facilitator and the two developers. As part of the process, we explored MicroTinker in teaching activities in two different prototype trials (see Figure 7).

Workshop 3 Prototype Evaluation. This was a one-hour workshop with a group of five high school teachers in informatics, set up to get didactic feedback for further iterations. It took place in a meeting room at the university, with two researchers present for observations. The Facilitator presented the tool, the teachers tried it out in several exercises and provided feedback and ideas for further development.

Workshop 4 Prototype Evaluation. We iterated on the exercises and the tool that were then tried out in a two-hour workshop targeting children aged 10-15. It took place in the robotics lab at the university with eight child participants, one parent, three researchers, and the Facilitator.

4 Artifact Ecology Analysis of Programming Workshops

We start by presenting the artifact ecologies of the programming workshops by describing the orchestration of activities by the facilitator based on the facilitator's intentions with regard to technology and layout of activities. Then, we highlight observations from the adoption of the orchestrated ecologies by participants during the different activities.

4.1 Orchestration

For *Workshop 1 Technology Play* and *Workshop 2 Robot Art*, the Facilitator prepared orchestrated ecologies of different artifacts for the participants. Orchestration in the context of artifact ecologies [46] describes the process of aligning constellations of technologies between the involved actors in a group. *Workshop 1 Technology Play* and *Workshop 2 Robot Art* were mainly pre-orchestrated by the

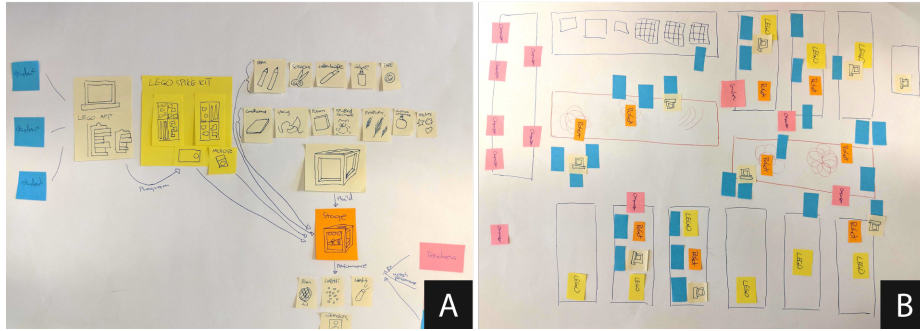


Fig. 3. Examples from the visual mapping in the artifact ecology analysis. (A) Overview of *Workshop 1 Technology Play* (B) Layout of *Workshop 2 Robot Art*.

Facilitator based on the assumptions of how the ecologies would be adopted by participants in the activity. During the activity, the participants adopted from the pre-orchestrated potential ecology [33] which are all artifacts available to the participants. The orchestration included devices, software, other building materials (LEGO bricks, cardboard, paper), and tools (scissors, glue, knife). This process of orchestration was planned by the Facilitator based on the intention of the specific activities and happened on different levels: both for the individual ecologies of participants working on the same project (either individually or in groups) as well as the overall ecology of all the materials in the room. These were set up in the same way for all groups and formed the overall ecology of all the actors taking part. For instance, in *Workshop 2 Robot Art* the ecology of one group of three was a laptop with one robot to create an art piece and together with all the groups in the room and the Facilitator formed the overall ecology.

Technology. In both observed workshops, participants used LEGO Spike Prime to control sensors and movement with a block-based programming language. The activities included various other building materials such as LEGO bricks and pen and paper in *Workshop 2 Robot Art* and string, stuffed animals, cardboard, feathers, foam, and stickers in *Workshop 1 Technology Play*. The Facilitator intended for participants to “*express [themselves] by means of programming*” where physical computing provided opportunities to learn programming: “*It’s not very easy to make the correspondence to what’s happening on the screen and then the program, as it is with robots or light or movement*”. Both *Workshop 1 Technology Play* and *Workshop 2 Robot Art* revolved around a shared object that the group built together (a drawing robot and a music stage) that was used in an exhibition or performance at the end as a shared activity. The participants approached the task independently in groups with the goal of enabling self-expression: “*I think you can make them program, if it has a purpose and [...] they end up with something that expresses themselves, within that purpose*”. The

Facilitator took on the role of assisting the groups with achieving the goals they had set for themselves.

The selection of technology happened by negotiating a tension between *why* the technology was used, *what* it was used for, and *how* it was used [14]). For instance, in *Workshop 1 Technology Play*, the participants were not intended to learn how professionals code, instead, they were supposed to experience being creative with computation (*why*) by controlling sensors and actuators (*what*) through programming with whatever means were available (*how*).

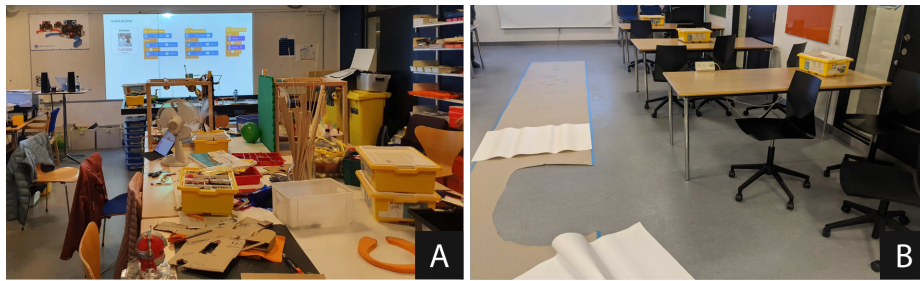


Fig. 4. Layout: (A) *Workshop 1 Technology Play* , (B) *Workshop 2 Robot Art*.

Layout of Activities. *Workshop 2 Robot Art* was set in a bigger classroom with desks for each group on the sides of the room (see Figure 4). On one side of the room, there were desks with materials such as paper, LEGO bricks, and writing utensils for participants to pick up if needed. Additionally, a large strip of paper was taped to the floor in the middle of the room between the desks where participants could test out their drawing robots.

Workshop 1 Technology Play, was a series set in the robotics lab of the university, a medium-sized room with a big table in the middle (see Figure 4). The robotics workshop lab had multiple different materials such as LEGO, fabric, stuffed toys, and cardboard that participants could use.

Workshop 1 Technology Play and *Workshop 2 Robot Art* focused on work in groups. This was reflected in the spatial organization of the workshops and how the Facilitator orchestrated the ecologies. Both *Workshop 1 Technology Play* and *Workshop 2 Robot Art* provided a shared desk and shared paper for interactions between groups, enabling participants to see what the other groups were doing. For the Facilitator, this spatial organization was intentional: “*I do not tell them they can take a piece of paper from the table and sit at their own table to do drawings. In the beginning, I say: ‘Do it without the pen in the beginning, on the floor, so it doesn’t fall down. Then do it with a pen on the common paper [...] to make some initial drawings... and finally, do it on your own paper.’*” with the goal to “*get some building activity that we have in common in the middle*” and create “*something like a fire camp, where we can sit around and do something*”.

For the Facilitator, the goal was to create a shared place where participants could meet and communicate: *“To make the room inviting, to stand up and draw in the middle, because then they see each other and see each other’s activities and maybe talk to each other”*. The Facilitator wanted to create a layout where the ecologies of the individual groups were visible to the other groups to create awareness of the joint activity.

4.2 Adoption

In the adoption of the orchestrated ecologies, participants used the different artifacts provided to them both in ways that were intended by the Facilitator and in unanticipated ways. In the following, we highlight findings regarding shared and common objects, copying, and collaboration.

Common Objects. The focus of the common object in *Workshop 1 Technology Play* changed throughout the activity. At first, the groups made sketches of their stages, then they built the stage with the different singers, dancers, and decorations, and finally, they integrated the motors of LEGO Spike Prime to make the elements move. Instead of working mainly with LEGO Spike Prime, participants spent a lot of time decorating their stages and had to be pushed by the Facilitator to integrate the technology into their stages. The Facilitator remarked that *“a lot of you will do what you are good at with the materials that I have around the table, which is not programming and building with Lego [...] and that’s what happened with the girls [...] they put up this Christmas stuff instead of making it turn”* suggesting that the participants focused on what they already knew and were good at. The Facilitator had to encourage the participants to bring the technology back into the activity since they *“didn’t see the LEGO as material in the design process”*. As a result, the Facilitator was considering changing the activity for future workshops by starting with the technology for the stages. While the activity was structured by the Facilitator using different materials, the participants adopted these in ways that were different and unintended.

Figure 5 illustrates how the common objects changed as the activity in *Workshop 1 Technology Play* unfolded. In Figure 5A, the common object was the laptop and robot shared by pairs of children, the large screen shared by all in the room, and the table that all pairs were gathered around. In Figure 5B, the common object was mainly the robot and the laptop with which the groups could make the robot move. In Figure 5C, the common object was no longer the digital technology but pen and paper, used for dreaming up a vision and idea for their final product as a sketch. When the sketch was done, the physical materials were allocated and assembled for construction. When the physical materials started to take over, the Facilitator reminded the participants of incorporating movement and light into the stage, so that the physical and digital materials would merge (Figure 5D). The product, the stage, the motors, and the laptop were the shared object within groups, while the groups were also aware of and inspired by each other’s objects. By the end of the activity, (Figure 5E), the products were

presented and exhibited to parents and families, and the object shared was now also a part of a larger ecology of objects being on show. The workshop participants were simultaneously working, collaborating, and focusing on the objects of their activity [11], where these objects were held in common [44]. However, they changed through the process and were always intermediary [33].

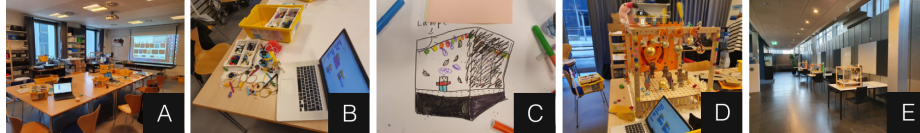


Fig. 5. Examples of common objects from the early, middle, and final stages of the workshop series *Workshop 1 Technology Play*. (A) Initial setup, (B) Robot, (C) Sketch, (D) Stage, (E) Performance and exhibition.

Copying and Collaborating. For *Workshop 1 Technology Play* and *Workshop 2 Robot Art*, participants worked in groups on a shared task. In addition, the Facilitator wanted to enable cross-group interaction and communication among groups so that they could “see each other and see each other’s activities and maybe talk to each other” to “make sure that they knew, what each there were doing”. The visibility of the ecologies of the groups was also meant to enable copying of what other participants were doing. This was rooted in the Facilitator’s belief that “normally in their play culture, they [...] go out into the playground and then they copy and remix what the other kids are doing”. By arranging the room to enable visibility between groups, the participants started picking up elements of the others’ stages and when one group would discover a new feature, like playing sound, the other groups would follow. In *Workshop 1 Technology Play* and *Workshop 2 Robot Art*, the spatial organization and group constellations changed over time. Especially in *Workshop 2 Robot Art*, participants were seated only in the beginning and then spread out over the whole space, some sitting on the floor in groups or on the desks. First, the focus was on assembling the robot, then on programming and making it move, and finally on testing out different robot movements to create an art piece. The activity centered on the shared piece of paper on the floor that the robots would draw on, and participants walked around to grab materials or look at the work of other groups. In *Workshop 1 Technology Play*, participants similarly started seated and would then move around the table to other groups or to shelves for materials. In this case, the groups transitioned to different configurations of the spatial arrangement of their tools depending on the stage of their projects.

4.3 Summary of the Artifact Ecology Analysis

The findings of the artifact ecology analysis demonstrate the link between the Facilitator’s intention, orchestration of the room and the artifact ecology, and

the participants' adoption as the activity unfolds. This follows findings from Barkhuus and Lecusay [4] pointing to the importance of acknowledging already established infrastructures in the learning environment, and that those infrastructures are flexible enough for adjustment. Flexibility was needed as the Facilitator's intention and orchestration were supported by the room and physical materials, but less so by the technology: The software environment for motors and sensors was not designed for sharing between different groups and the participants would need to physically gather around one computer to collaborate or to view code from different groups. This is a reason for exploring possibilities of how to remediate the material support and these findings served as a starting point for the PD process.

5 Prototyping MicroTinker

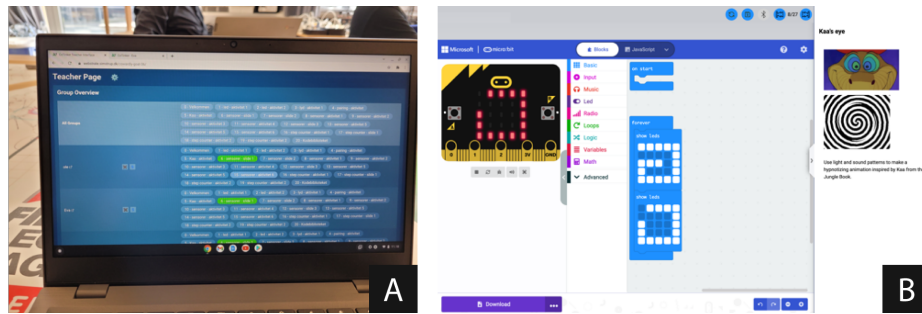


Fig. 6. MicroTinker. (A) The teacher page with groups and exercise repository, green marks in which exercise each group is. (B) The participant page with an embedded MakeCode editor and instructions for the current step of the learning activity.

Building on the findings from the artifact ecology analysis, we employed an iterative PD process in order to develop and try out a new digital teaching tool for facilitating programming workshops in non-formal learning contexts. Particularly, to explore how the digital aspects of a learning activity could become a common object. The goal of exploratively developing the tool was to facilitate collaboration and sharing of code between participants and enable the Facilitator to share and discuss the code of individual groups with the whole group. Based on previous experience in building collaborative systems and software to facilitate learning activities, we used CoTinker which is an in-house developed platform for creating web-based collaborative and flexible learning environments for programming and computational thinking. The teaching activity imagined together with the Facilitator revolved around the different sensors of the micro:bit. The tool and the content were intended to be used in a teaching activity where small groups would work together in a room with a facilitator. The central

idea was a stepwise tutorial where each step can include both the instructions and the interactive means to solve the given part of the tutorial. Through the PD process, we came to imagine two main parts: *the teacher page* where the Facilitator can administrate groups and steps, and the *participant page* where the participants program and solve the steps of the learning activity.

Participant Page. The participant page is what the participants load on their laptops and where they program in groups (Figure 6). The page integrates a version of the MakeCode interface and an additional panel with instructions from the Facilitator. An activity is divided into steps that participants can go through. A step includes instructions and/or inspiration for the given assignment and a pre-loaded starting point for a micro:bit program. Additionally, the participant page enables participants to share their code in a code library to access and reuse their programs. The participant page is collaborative, and anyone with the link can modify and access the project in real-time.

Teacher Page. The teacher page functions as a space for the Facilitator to manage the groups and the learning activity. The Facilitator can access the participant page of all groups to, for instance, share their work with the whole class on a project or large display. The Facilitator sees exactly the same as the groups and can collaboratively edit the micro:bit code. The teacher page shows an overview of the progress of each group, which enables the Facilitator to move all the groups to the same step in the learning activity.

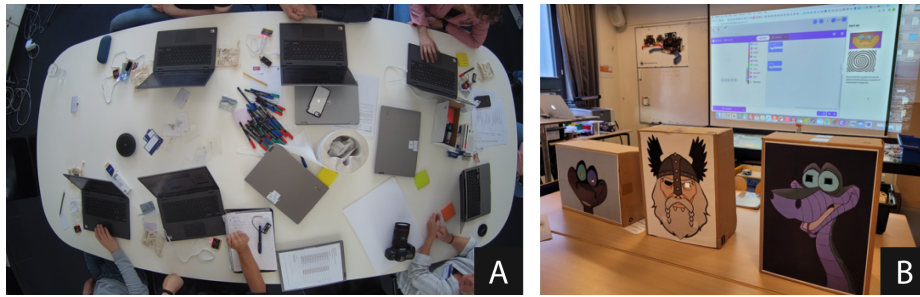


Fig. 7. Prototype evaluation. (A) With high school teachers, (B), with children.

5.1 Learning activity

The Facilitator authored an activity for MicroTinker consisting of several exercises for the micro:bit which all revolved around the sensors of the micro:bit such as sound, light, and the accelerometer. The exercises involved creating patterns on the light panel of the micro:bit to create hypnotizing eyes (of a snake

or Odin) by holding the micro:bit behind a cardboard cut-out, and the creation of a step-counter where the micro:bit can be attached to a shoe.

6 Exploring MicroTinker

In the following, we report on the findings from the PD process of developing MicroTinker with regard to sharing and common objects in the workshops and how the tool shaped and integrated into the teaching and orchestration process.

6.1 Sharing and Common Objects

During the observed workshops (*Workshop 1 Technology Play, Workshop 2 Robot Art*), sharing of the physical products (the stages, art pieces, and robots) was done through the spatial layout of the activity: *“you can go around between the groups and you can see what they have been building.* However, this was not the case in the same way for the code: *“but you can’t see what they’ve been programming because you [seldom] look at the computer”.* Therefore, one of the main goals for the development of MicroTinker was to make the digital material, i.e., the code, accessible and shareable like the physical material: *“each have their own app and you can’t share it [...] There’s a lot of places where the programming is hidden somehow. This tool can make it as visible as the physical stuff”.* For the Facilitator, being able to share the digital material could make participants aware of the shared activity and show the value of seeing other participants’ solutions: *“the possibility of sharing screens made it more explicit that we also have this to share [...] Instead of sitting each with their own screen we are aware that we all have a screen, and we’re doing the same thing, and we’re doing it different ways, and maybe it’s a good idea to see what the others are doing.”* In this case, the option of sharing code had the potential of creating awareness of the code as a common object between participants within the wider context of the joint workshop activity.

During *Workshop 4 Prototype evaluation*, sharing of the products was enabled in the same way as in the observed workshops through the room layout, with cardboard cut-outs at the front where the participants could try out their programs making these visible to the other participants (see Figure 7). Sharing with all participants was mediated through the large screen at the front where the Facilitator could open participants’ programs. In this case, sharing code and sensor values on the large screen facilitated communication between participants by transitioning between individual work and shared group activities.

The code became common between the participants, as did the teaching material which had previously been PowerPoint slides that were now integrated with the code editor. However, after reflecting on the prototype evaluations, the Facilitator found it better if the slides would not show on the participants’ screens in the tool as *“there’s no reason for them to see the whole screen as a PowerPoint”.* It suited the Facilitator better if participants would look at the slides on the projector to help attract their full attention. In this case, having the

shared focus of the group during instructions was more useful to the Facilitator than having the teaching material shared on all laptops.

6.2 Between Improvisation and Structure

At first, the Facilitator was skeptical of CoTinker as it would be “*getting rid of the teacher*” and thus did not fit with the Facilitator’s way of teaching: “*my first reaction was [...]: ‘come one, that’s not how you teach’*”. For the Facilitator, it was important to maintain an active role during the teaching whereas the initial CoTinker prototype was focused on supporting autonomous work of students. Therefore, in the PD process, one goal became to develop a tool that would give the Facilitator control and an active role during the workshops.

There was a tension between how the Facilitator was involved in the progression of the prototype evaluation workshop with children and how this role was externalized through the tool: The Facilitator wanted to be able to orchestrate the activity while having room for improvisation during the workshop. On the one hand, the tool provided fine-grained steps: “*what the tool gives me is to have extremely simple programming exercises in a series where every step is very minor*”, on the other hand, a balance was needed with the different progress of participants and the freedom to adapt the teaching to that: “*somehow you need to plan using CoTinker so that you can have some [...] do whatever they like, and some of the other students do what I say they should do*”. Whereas previously these activities were spontaneous and improvised during the workshop, the tool made the Facilitator plan and externalize parts of it: “*but normally that’s part of the planning of the activity on the fly [...], it is not something you do beforehand sitting with a tool. But that [CoTinker] tool, as every other tool, makes you aware of how you should plan the teaching activity*”.

The tool made the Facilitator reflect on the process and the individual steps during the workshop: “*then I would realize where I should make sure that everybody was at the same slide as I, or where should I let them do something else?*”. The Facilitator thought that there could be benefits to this, such as making teachers reflect on the different aspects and steps of the activity serving as an educational tool for planning teaching: “*maybe for an inexperienced teacher it might be good to have [...] the activities and the planning of the activities within embedded in such a tool, so they can learn how to teach programming by means of the tool*”. The tension between structure and improvisation highlighted that externalization of the facilitation through the tool was an important design concern and balance to maintain.

6.3 Integration of Functionality

MicroTinker integrated functionality that the Facilitator had previously used with other tools and it thus became a substitute. Before, the Facilitator made slides in PowerPoint to plan workshops. As these functions became integrated, the Facilitator needed to figure out how to orchestrate the workshop: “*it was a learning process to figure out how to prepare some learning activity by means*

of a tool that, it's not PowerPoint but it's like PowerPoint. It's not sharing a common screen, [...] I show something up there with the tool on my screen and then they are supposed to do it with their tool on their screen. These things I really had to think about it and adjust to [...] the media of the new tool". When reflecting on this, the Facilitator remarked that the tool could take a role that was not only specific to the context that we had designed it for: "now it's like any other tool. It's PowerPoint with a programming tool integrated or the other way around, and then you can share screens in a more elegant way. That's it. That's a tool you can use for anything. It's not built into the tool how to use it".

Similarly, when adopting the tool in *Workshop 4 Prototype evaluation*, the Facilitator remarked that using it required a conscious adaption throughout the workshop facilitation: "there [was] one occasion where I forgot that I can actually see what they're doing [...] and I should have said 'let me look at your page' so I can correct or see what's wrong [...] that's because I'm not used to using it like that." Other functionalities integrated into the tool, like the ability to move all participants to the same step, were not used by the Facilitator: "I actually didn't use the tool to make them go to a specific page because normally you would just shout out 'are you all on this page?'"

Using MicroTinker changed the dynamics of the artifacts previously used by the Facilitator and required a rethinking of the orchestration and adoption for the tool to be integrated into the new artifact ecology in the wider context of the activity and teaching practice.

7 Future Work and Iterations

In the current version of MicroTinker, the focus was not specifically on the preparation of teaching material. Instead, these steps involved the software developer.

The Facilitator wanted to be able to author the teaching material in future versions: "I need to be able to write my own material [...], with PowerPoint you sit and then you mingle until the very last moment before you present it to people. And here I barely remembered what I had put on the slide I sent [name] a week ago". The workflow of producing teaching material did not fit with the practice of the Facilitator when preparing workshops. Designing and developing authoring tools that would allow teachers to create, edit and adapt learning activities through a graphical direct manipulation interface is a next step beyond the scope of this prototype.

The Facilitator reflected on the prototype evaluations and how using a more stable version of MicroTinker to prevent technical difficulties in longer, consecutive workshops would provide more insights into the sharing functionality. For instance, during the *Workshop 4 Prototype evaluation*, participants did not use the shared code library: "they actually do not use that they can save code. That might be because it's not a long enough sequence of activity". Similarly, the Facilitator was interested in organizing workshops with a higher level of complexity and thought that this would make differences more pronounced: "I would be curious about what will happen if they see each other's programs when the pro-

programming is a little more complex than we had in the workshop. Because then you can see that they express themselves by means of these blocks differently”.

8 Summary and Discussion

This study contributes to the understanding of programming in non-formal learning contexts that are still under-explored [52,36]. In related work, the components and intentions of each study vary significantly [36], not only in the variability of countries, and disciplines but also in their scope [36,25,52,42,23,4,41,35]. Related work shows that it is relevant to consider the characteristics and aim of facilitators, the tools and materials available, the spaces, and the social and cultural structures [4,52,36]. We have done so by investigating the artifact ecologies and common objects in a non-formal learning environment of six programming workshops. We have used the findings of these analyses for a PD process of a new teaching tool together with a Facilitator of programming workshops.

The findings from the artifact ecology analysis demonstrate the link between the Facilitator’s intention, orchestration of the room and the artifacts, and the participants’ adoption as the activity unfolds. The tool developed served as an exemplification of how these insights can be turned into design constructively [2,6]. This is only one such possible design and its usefulness lies in the PD process. The digital tools did not support the collaborative setup to the same extent as physical artifacts, as also noted by Roumen and Fernaeus [47]. The artifact ecology analysis and visual mapping enabled us to identify and analyze common objects and their roles as mediators of sharing for the participants. These findings provided opportunities to design a tool to address code sharing, creating awareness among participants of the joint activity, seeing the digital material as common, and enabling the Facilitator to share and discuss the code of individual groups with the whole group. As such, the tool complements and extends the traditional laptop programming paradigm, which tends to restrict collaboration rather than encourage shifting of roles and sharing of experiences [47], and addresses the identified lack of a social context for learning programming [31].

Through introducing CoTinker as a provotype, we ended up with additional design implications with regard to facilitation. It helped externalize the Facilitator’s needs and practices for how to structure the activity, and the role of the tool and the Facilitator became clearer. These findings extend previous knowledge on the role of facilitation style and the facilitator in technology education [36,20,10,50], and shed light on the importance of the facilitator’s practices and ability to identify the types of instructional support necessary for individual needs [18,5,40]. In contrast to formal learning contexts, the purpose of a learning activity in a non-formal programming context can be set either by the facilitator or the participants [36,20].

The artifact analysis helped gain insights into how the Facilitator orchestrated the activities with regard to the material support, but less so on the process and practice of the orchestration itself. By introducing a new tool into the Facilitator’s teaching, the process of orchestration and authoring of teaching

material changed as tools previously used got integrated into MicroTinker. An authoring tool to support the process of orchestrating the workshops is needed to support the Facilitator’s planning and preparation. This requires a thorough understanding of how these activities unfold which is a topic of future work.

9 Conclusion

We have presented results from a PD process with a facilitator of programming workshops in a non-formal learning context. We conducted an artifact ecology analysis based on observations and interviews. The results have been used in an iterative PD process in which we developed a new tool to support collaboration and sharing of code.

The empirical setting is rich with multiplicities of artifacts and objects, some of which are everyday and mundane, while others are rather specialized for the teaching situation. The Facilitator sets up and orchestrates combinations that are then shared and adopted and held in common by the groups in entire workshops as they are both able to monitor the activities of other groups and explicitly share them with the help of the Facilitator. The common objects represent the workshop participants’ ideas of the end product, their intermediate designs along the way, and the steps in the design process. In this study, we have seen how both slides and code serve as common objects as they move from being part of the orchestration of the Facilitator to becoming parts of the joint end product of the groups. It is important to notice that they are not only shared material, and they help students and the Facilitator share a vision of a future outcome of the groups’ building process.

The type of study presented here can be useful for others who intend to better understand both the explicit and implicit social and material structure of non-formal learning environments. Analyzing the Facilitator’s orchestration and intention with the artifact ecology and setup, and the participants’ adoption, enabled not only identifying what dynamics impact the artifact ecology, but also more specific needs and new technological possibilities.

Acknowledgements

We would first like to thank Ole Caprani at Aarhus University for his dedication and time. The research is co-funded by the European Union’s Horizon 2020 Research & Innovation programme under Grant Agreement no. 870612 for the ySkills project. This work also was supported by the European Research Council (ERC) under the European Union Horizon 2020 research and innovation programme (grant agreement No 740548), by IT-Vest networking universities (grant agreement No AU-2020-49), and the Carlsberg Foundation (grant agreement No CF17-0643). The authors would like to thank the Co-Coders organization, and finally CAVI.

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