International Journal of Child-Computer Interaction, vol. 26 (2020), article 100199.
Author version. Published version at: https://doi.org/10.1016/j.ijcci.2020.100199

How Is Learning Scaffolded in Library Makerspaces?

Árni Már Einarsson, University of Copenhagen, Denmark. arni.mar.einarsson@hum.ku.dk
Morten Hertzum, University of Copenhagen, Denmark. hertzum@hum.ku.dk

Abstract. Libraries have adopted makerspaces to promote a maker mindset and skills in using technology. In this paper, we examine how learning is scaffolded in library makerspaces. Based on interviews in fourteen Danish library makerspaces, we identify seven scaffolding approaches across formal, non-formal, and informal learning activities. The scaffolding approaches include topic-driven activities for schools, object-driven events for children and their parents, and community-driven activities, which are mostly attended by adults. We find that in spite of their focus on learning, the makerspaces provide limited scaffolds for skill progression. In addition, the scaffolds must span multiple skills but tend to focus more on the users' skills in using the available tools than on their skills in defining meaningful projects. A final challenge faced by the makerspaces is that to scaffold community-driven activities, the makerspaces must accept that it is a continual effort to balance community claims to the space against openness to newcomers.

Keywords: makerspaces, scaffolding, learning, libraries

1 Introduction

Makerspaces are emerging in diverse settings as a local space where individuals can meet, make, learn, and share [1]. Libraries are one of the institutions that have embraced these new spaces [2–8]. It has been argued that makerspaces and libraries are a natural combination because makerspaces in libraries offer "*a framework by which shared core library and community values such as equitable access to information, resources, and opportunity for lifelong learning can be reconciled and amplified*" [5]. Yet, providing and equipping the space is not enough to create a successful makerspace. It is also necessary to invite activities that attract and sustain user interest and development. That is, it is necessary to scaffold learning.

Scaffolds seek to facilitate learning by constraining the possibilities for action [9–11]. To succeed, they must ensure low barriers to entry, while at the same time providing the challenges necessary for deep and sustained learning. With too few constraints, the possibilities may be vast but the barriers to participation are high because the users must themselves discover what is possible, bring the ideas, plan their project, build the skills, overcome the setbacks, and so forth. With too many constraints, the possibilities are too few, and user interest quickly dwindles. On the basis of interviews, this study explores *how learning is scaffolded in library makerspaces*. Because the scaffolding differs across learning activities, we distinguish among scaffolds in formal, non-formal, and informal learning activities. The investigated library makerspaces are located in Denmark and have activities for schools, families, and the general public.

In the following, we review related work on library makerspaces and scaffolding, account for our method, and present the results of the interviews conducted. On this basis, we discuss the challenges of scaffolding skill progression, developing multiple skills, and attracting communities while also ensuring access for newcomers.

2 Background

Makerspaces have spread and become popular in less than two decades [5]. In a survey of public libraries in 31 large cities across the world, Born et al. [3] find that 41% of the libraries have makerspaces.

2.1 Library makerspaces

The notion of a makerspace is an umbrella term for creative spaces such as hackerspaces and FabLabs "*[...] where Makers congregate and, ideally, have access to the tools, spaces, and resources that help them create the things they Make*" [8]. Makerspaces are located and configured in different ways in the library space [12] to serve the needs and wishes of their local communities. Some makerspaces provide simple tools and become venues to support creative and accessible STEM experiences for children, families, and underserved group [4,13,14]. Other makerspaces aim to engage users in a community of practice around advanced digital fabrication machinery [15]. Still other makerspaces have no permanent physical location but pop up on occasion to facilitate maker activities [8,16]. In spite of their variety, library makerspaces center around similar goals [6]:

- To expand library services through additional offerings
- To foster engagement and involvement of the local community
- To promote equitable access to technological tools
- To encourage participatory learning

Pursuing these goals involves a belief that libraries should be more like kitchens and less like grocery stores [7]; that is, they should be places of creation rather than consumption. In this way, makerspaces contribute to the reorientation of libraries away from a mainly book-centered approach and toward attracting new users and collaborators [6].

Makerspaces have hands-on qualities that hold potential for facilitating learning that is tangible, imaginative, and stimulates the learner's feeling of self-efficiency [17–19]. For example, studies report that makerspaces "*offer a safe space to design, create, fail and try again*" [20], that the provision of a library makerspace "*would be empowering*" to its users [4], and even that the learning has an aspect of activism in that "*makers aim to intervene to create a world different to the one we live in*" [21]. In a study on youth makerspaces in libraries and schools, Li and Todd [22] find that all interviewed users enjoy the process of making while they learn future-relevant STEM-based, artistic, and collaborative skills and build friendship with other users. However, Willett [7] strikes the cautionary note that it is often unclear whether the users of library makerspaces experience an urgent need to create, just as it mostly remains unspecified how the empowerment manifests itself. It has also been found that whereas failing epitomized learning in the eyes of makerspace mentors, the teenage users of makerspaces equated failing with not learning [23]. Specifically, many of the teenage users were disinclined to take on larger projects and, instead, preferred fast projects that fitted into 30-45 minute timeframes. Such brief timeframes left little time for failure and learning. Thus, a 'maker mindset' cannot be assumed. To attract and sustain broad interest in a makerspace, libraries must be prepared to cultivate such a mindset. Otherwise, library makerspaces may attract a fairly narrow group of users.

The maker movement emphasizes informal learning, sometimes to the extent of creating a polarization between hands-on, learner-led, playful, informal learning and instruction-style, tedious formal learning [7]. Many library makerspaces are, however, involved in educational activities with schools, either through a collaboration between a public library and a school or because the makerspace is part of a school library. In both cases, the makerspace hosts activities that are embedded in a formal curriculum. As a commendable example, Thanapornsangsuth [24] shows how a four-day makerspace program engaged Indian eighth-grade students (12-14 years old) in identifying and working to solve community problems. One of the student groups created a prototype diffuser for lemongrass oil to keep mosquitos away. A key result of the study was the importance of purpose and passion in uniting the students around a group goal and in driving them to persist through challenges. However, the four-day program required a staff of 19 people to support the about 50 students. At the informal end of the spectrum, Taylor et al. [21] show that makerspaces may primarily be hubs of community. For example, the Westhill Men's Shed provided a communal workspace for older men with mental health issues [21]. In these makerspaces, the fabrication activities mainly serve as a scaffold for coming together, learning from each other, and socializing.

2.2 Scaffolding

Wood et al. [25] introduced scaffolding as a metaphor for the assistance a tutor provides to enable learners to solve a problem, carry out a task, or achieve a goal that would be beyond their unassisted capabilities. Subsequently, the scaffolding metaphor has been employed in a wide variety of settings, mainly in education [e.g., 26] but also in museums [e.g., 10], makerspaces [e.g., 27], and studies of knowledge work [e.g., 9]. Scaffolds provide both cognitive and motivational assistance [11]. Using the six scaffolding functions identified by Wood et al. [25] as examples, cognitive assistance includes reducing the degrees of freedom in the task, marking critical task features, and demonstrating task solutions; motivational assistance includes enlisting the learners' interest in the task, maintaining their direction of focus to keep them in pursuit of the task, and controlling frustration. In makerspaces, the learning objective served by scaffolds includes a concrete objective, such as producing a specific object, as well as the intangible objective of learning new methods, stimulating interest in making, and taking part in a community [6,7].

Scaffolding, especially the cognitive assistance, is often linked to constructivist learning theory and its idea of the zone of proximal development [28]. The zone of proximal development is the distance between a learner's current level of development and the potential development level that can be achieved through hints, guidance, or help from more knowledgeable educators [28]. It resembles one-on-one scaffolding in which an educator scaffolds a task for a learner. Another important class of scaffolds is peer scaffolding in which the hints, guidance, or help are provided by other learners rather than by an educator [11]. A third class is material scaffolds, such as instruction sheets, predefined exercises, and computer-based tools [11]. While one-on-one scaffolding and peer scaffolding are soft in that they are interpersonal and dynamic, Saye and Brush [29] contend that material scaffolds are hard in that they are preplanned and unchanging. Irrespective of their class, scaffolds facilitate certain actions and constrain others. They "*structure human activity by supporting and guiding it, while at the same time configuring and disciplining it*" [9]. That is, scaffolds in library makerspaces are the sociomaterial conditions that facilitate users at different stages of learning in their individual progression.

Scaffolds are intended to be temporary. They are introduced to assist the learner in progressing and they are gradually removed as the learner gains skill at the scaffolded task. This fading distinguishes scaffolds from permanent types of assistance, which are designed to remain available and be used whenever the task is performed [11]. When a scaffold is faded away, the learner has achieved an increased level of competence and autonomy [25,26]. Scaffolds also differ from other types of assistance by simultaneously simplifying tasks and highlighting their complexity. The simplification serves to make the task easier to accomplish. The highlighting of its complexity serves to shape the learner's understanding of the task, problematize its content, and thereby provide more productive opportunities for learning [30]. Belland, Kim and Hannafin [31] study scaffolding in the context of problem-based learning – a setting with many similarities to makerspaces. They argue that educators should provide scaffolds that establish task value and promote autonomy, belonging, emotion regulation, mastery goals, and expectancy for success.

2.3 Formal, informal, and non-formal learning activities

In library makerspaces, learning is scaffolded through formal, informal, and non-formal activities. Formal learning activities are often pre-structured for a group of students in an educational institution [32]. There may be room for student projects, but the formal activities are structured by their temporal boundaries and instructional design. Several studies point to tensions between, on the one hand, curriculum planning and learning goals and, on the other hand, the interdisciplinary and exploratory aspects of learning in a makerspace [17,33]. However, curriculum planning and learning objectives scaffold learning in ways that help clarify to the students what and how to do, and thereby support progression in the students' learning.

In contrast, informal learning is self-directed, incidental, and interest-driven [34]. It happens outside formal educational contexts and is structured around learner-initiated projects rather than pre-set educational objectives. Informal learning may be individual, but in relation to makerspaces its communal and social aspects are often emphasized [6,21,35]. Scaffolds for informal learning should not prescribe activities or goals but rather map out the space of possibilities. Though everyone is welcome in informal activities, there are social and technical barriers for non-experienced users to enter the informal makerspace activities [21,36].

Non-formal activities are discretionary, structured or semi-structured activities [37]. They often aim to develop specific technical skills or to invite new users into the makerspace [21,36]. For instance, Dreessen and Schepers [36] discuss strategies that invite non-experienced users to a communal makerspace through strategies for bridging non-formal and informal activities.

3 Method

To map approaches for how learning is scaffolded in library makerspaces, we conducted semi-structured interviews [38] with practitioners in fourteen library makerspaces in Denmark. Prior to the interviews, the study and its data collection were approved by the institutional review board at our university.

3.1 Procedure

Because we set out to map scaffolding approaches, we needed variety in our sample. We sought variety in the type of makerspaces, their regionality, and their spread across urban and rural municipalities. The makerspaces were selected on the basis of a list of all municipal libraries in Denmark. For each library, we searched on the library website and Google for "maker [+library name]". This way, we identified a total of 23 libraries that hosted makerspaces or other recurring maker activities. For the interviews, we recruited 14 libraries through purposive sampling [38] with the criteria to represent a large proportion of the population and reflect variation in type and geographic location. The 14 library makerspaces are summarized in Table 1. They represent all regions in Denmark and span urban (7 makerspaces), rural (6 makerspaces), and intermediate (1 makerspace) municipalities. In the table, the type of makerspace is classified as:

- Pop-up makerspace: Makerspaces that have no designated area but host recurring activities with simple tools such as electronics, robotics, and creative materials.

- Single-room makerspace: Makerspaces with a designated area in the library and a modest tool package including laser cutter, 3D-printers, electronics, robotics, and creative materials.
- Multi-room makerspace: Makerspaces with multiple designated areas in the library and a large tool package including machinery such as a CNC-mill, laser cutters, and materials for wood working.

The majority of the interviews were conducted in the makerspace and combined with a tour of the makerspace. Three interviews were conducted over the phone. In four libraries, two makerspace practitioners with different roles attended the interview. All interviewees had experience in planning and conducting activities in the makerspace. Prior to the interviews, the interviewees individually consented to take part. The consent procedure involved that all interviewees were informed about the research aims, the data protection policy, and the use of anonymized quotations in research publications. The interviews were audio-recorded and lasted between 45 minutes and 2.5 hours.

Alias	Age of makerspace (years)	Types of activities conducted in the makerspace	Type of makerspace	Interview length (minutes)	Interview medium
L1	3	Formal, informal	Multi-room	101	Face-to-face
L2	2	Formal, informal	Multi-room	155	Face-to-face
L3	1	Formal, non-formal, informal	Multi-room	70	Phone
L4	3	Formal, non-formal, informal	Multi-room	81	Face-to-face
L5	4	Formal, non-formal, informal	Single-room	62	Face-to-face
L6	2	Formal, non-formal, informal	Multi-room	63	Phone
L7	1	Formal	Single-room	50	Face-to-face
L8	2	Formal, non-formal, informal	Multi-room	127	Face-to-face
L9	2	Formal, informal	Single-room	72	Face-to-face
L10	2	Formal, informal	Single-room	94	Face-to-face
L11	2	Non-formal	Single-room	73	Face-to-face
L12	1	Non-formal	Pop-up	62	Face-to-face
L13	1	Non-formal, informal	Single-room	59	Face-to-face
L14	1	Formal, non-formal	Pop-up	60	Phone

Table 1: Data material

All practitioners were interviewed about the objectives of the makerspace, the organization of its activities, and the kinds of activities conducted. We asked the practitioners to describe how the different learning activities were organized, who attended them, and what objectives they served.

3.2 Data analysis

The interviews were transcribed and analyzed in NVivo 12. L14 is an exception because the transcription took place during the interview due to a dysfunctional recorder. To avoid misunderstandings in the transcript of L14, this transcript was sent to the interviewee for acceptance.

The data material was coded by the first author in a process interspersed with regular discussions among both authors about the direction and interim results of the coding.

In the analysis, the data were coded in three rounds. The first round of coding was guided by activity theory and consisted of coding the data from each makerspace for the elements in the activity system [39]. These elements were activities, objectives, roles, rules, tools, users, and community relations. In this precursory analysis, we focused on getting an initial understanding and overview of the data. The main outcome of this first round of coding was that it revealed the importance of the division of the makerspace activities into formal, non-formal, and informal learning activities.

Second, the data were coded for patterns specific to formal, non-formal, and informal learning activities. This analysis started by marking up the transcript passages about formal, non-formal, and informal activities (see Table 2 for definitions). These passages tended to be long because the interviewees described multiple aspects of the activities. The activities found were subject to pattern coding [40] that revealed distinct patterns in how learning was scaffolded. A total of seven scaffolding approaches were identified in this way. Each scaffolding approach represented a grouping of activities with a distinctive logic for constraining action and fading the constraints to drive the particular group of people participating in the activity toward its objective. The seven scaffolding approaches are the main result of this study and described in the next section.

Coding category	Coding criteria	Total number of codes	Spread of codes (number of makerspaces)
Formal activities	Activities that involve an educational institution such as a primary school, secondary school, special school, high school, or university. The objective is defined by the educational institution and library.	92	13
Non-formal activities	Activities that are open to the public but are pre-planned, scheduled, and promoted. These activities take place during a limited period of time. The objective is defined by the library.	85	14
Informal activities	Recurring activities or activities that allow users to attend the makerspace and use its tools for individual purposes. The objective is defined by the individual user.	115	14
Learning objective	The learning objective, or purpose, the practitioners aim to accomplish by scaffolding the users' activities.	109	14
Scaffolding technique	Techniques the practitioners use to facilitate learning in the makerspace. These techniques can be interpersonal communication, designing the flow of the activity, and selecting the materials.	122	13
Scaffolding barrier	Challenges, mentioned by practitioners, to the progress of learning. Barriers can relate to the specific technique, the type of activity, or to specific users. Challenges concerning the coordination among staff and the acquisition of materials are not considered scaffolding barriers.	67	14

Table 2: Coding Scheme

Third, we examined the data for the objectives pursued, techniques used, and barriers encountered (see Table 2 for definitions). This coding served to add further detail to the descriptions of the seven scaffolding approaches. It also provided the basis for a matrix analysis of which objectives, techniques, and barriers that occurred in formal, non-formal, and informal learning activities (see Table 3). Finally, relevant quotes were translated from Danish to English for presentation in the next section.

4 Results

To give an up-front overview of the results, Table 3 summarizes the results of our analysis, which led to the identification of seven scaffolding approaches in formal, non-formal, and informal learning activities. In the following, we examine the seven scaffolding approaches in detail.

	Formal	Non-formal	Informal
Conditions for scaffolding	Mandatory Pre-planned Objective defined with school	Discretionary Pre-planned Objective defined by library	Discretionary Not planned Objective defined by users
Approaches to scaffolding	Tool-driven (4) Topic-driven (3) Project-driven (4)	Object-driven (10) Tool-driven (4)	Self-driven (8) Community-driven (6)
Scaffolding techniques	Activity design Material selection Building on existing knowledge Exercises Instruction Peer-to-peer guidance Public presentations	Activity design Building on existing relations Material selection Competition Peer-to-peer guidance	Recurring meetings Formal rules of access and use Peer-to-peer guidance Collaboration with actors in the community
Learning objectives	Technical competence Design process Topics and concepts	Technical competence Design process Social relations and dialogue	Social relations Participation in the local community Technical competence
Barriers	School collaboration Customization	Little time for design process	Self-directedness Inclusion

Table 3: Overview of scaffolding approaches in formal, non-formal, and informal learning. The numbers indicate how many makerspaces that employ the scaffolding approach.

4.1 Formal Learning Activities

The formal learning activities are collaborations between the library and formal educational institutions. The activities are mandatory for the pupils and pre-defined in their duration, tools, materials, and learning objectives. The practitioners find that formal learning activities support *"reaching people that otherwise wouldn't come here"* (L4), help schools that are "*not ahead of the curve*" (L14), and help teachers under *"significant [time] pressure"* (L1) bring new tools into their classrooms. The practitioners also emphasize that a library makerspace provides a different "*social arena*" (L10) for learning less measurable skills: "*No child should come here to cram programming. [..] Schools teach children programming by setting up goals, measuring effectiveness in tests, and such things. Here our focus is on the passion-driven – on how you open up for your creativity and* *your passion to create something*" (L5). While such an environment can be a source of noise and distraction, it also provides students with opportunities to improve their technical, practical, collaborative, and reflective skills as well as to develop their interest in making. In our interviews, we found that formal learning activities can be tool-driven, topic-driven, and project-driven.

In the tool-driven scaffolding approach, the activity is designed for pupils to acquire the technical skills to operate the tools in the makerspace. The activity tends to be structured around detailed instructions. The practitioners begin with lectures and exercises and then allow more room for tinkering and playing with the tools: "*Usually, we instruct them in driving [robots] forwards, backwards, control speed, and stop. They learn this quickly and thereafter they continue making*" (L14). A similar activity design is found in a two-day course that introduces students to the machinery and methods in the makerspace, specifically entry-level programming. On the first day, students are introduced to programming and the micro:bit technology through lectures, and they learn to program a simple, digital dice. On the second day, the students work on exercises where they apply their newly developed technical skills to produce a personalized digital watch decorated with a laser-cut frame and a self-made strap. The watch is theirs; they can bring it home and wear it at school. While the scaffolds fade as these activities progress, it is only to a limited extent because the objects produced and techniques used are predefined. The lectures on the first day aim to teach the students how to use the makerspace tools.

In the topic-driven scaffolding approach, the objective is to use maker tools and materials to experience a topic in a new way. The topics are selected in collaboration with teachers and may for example be a book or a concept. The topic-driven activities combine traditional classroom teaching with makerspace activities. A school librarian, or the teacher, facilitates a discussion about the topic of the book and the author's background. Then, the students produce scenes or characters from the book: *"It is typically in Danish classes where the class has been working with a book. Then they come here and build some scenes [..] Some made fire with a fan, so it looked like flames"* (L8). Another practitioner contends that this approach gives the students a *"tactile experience"* of the topic and make them reflect collaboratively on their mental images of specific things in the book: "*There is drama when third graders need to agree on what to put on the poster[..] When working with others, you need to make compromises, sometimes kill your darlings, and accept that everyone must have a say"* (L10). Like the tool-driven approach, the topic-driven approach has pre-designed trajectories that combine lectures and group exercises. In this case, however, it is the building of a scene that motivates the activity. The choice of materials and technologies is restricted but it is up to the groups what they construct and how the materials are combined. This type of activity scaffolds a learning process that focuses on the students' reflection and negotiation of their images of literature. In using the makerspace tools to materialize their ideas, the students acquire technical skills, but the focus remains on the topic and process.

The project-driven scaffolding approach unfolds in longer-term collaborations between a school and a library. These projects often strive to produce something of value to the local community. Projects mentioned by the practitioners include students making signs for the local community (L3), coat hooks for the library space (L5), an escape room available for library users (L10), and solutions for a sustainable future (L4). For example, in L4, high-school students spend several months working on projects relevant to the UN agenda of sustainable development goals. Supported by teaching in innovation processes, the students define a problem, access technologies and expertise in the library makerspace, and devise a 'solution'. Finally, the students present their solutions at a local fair, hosted by the library in collaboration with the high school and a local university. In the project-driven approach, the learning objective centers around devising a design that is relevant for the local community. With that aim, students need to understand project-specific challenges, such as the social and technical challenges of energy consumption or the specific puzzle design for the escape room. In comparison to the tool-driven and topic-driven approaches, the library has less of an educational role of teaching and planning exercises. Instead, the library scaffolds the activity by assisting the individual projects and organizing the event for the final presentations.

The topic-driven and project-driven approaches benefit from designing the activity in collaboration with a teacher to meet educational goals. The tradeoff, however, is that it requires significant effort to plan and conduct these activities. Especially for projects, one practitioner explains: *"We make eight-month or six-week long projects so we simply can't reach all schools. Instead, we make big things and we get students who become proficient in using it [i.e., the makerspace and its tools]"* (L10). In contrast, tool-driven activities are designed by the makerspace and provided as a service to introduce students to the machinery in the makerspace and develop their technical skills.

4.2 Non-formal Learning Activities

Non-formal learning activities are discretionary activities that are pre-planned by the makerspace staff. The practitioners acknowledge that access to tools is not sufficient: "*You could think that now the doors are open and then everyone will come. But no. People don't. It requires a lot*" (L4). It requires scaffolding. The non-formal activities are open to the public but target a specific group, mostly children and families during weekends and holidays or adults and parents during evenings. The activities serve to increase the visibility of the makerspace and, thereby, recruit users for the informal makerspace activities. We find that non-formal activities are scaffolded in object-driven and tool-driven ways.

The object-driven scaffolding approach aims to engage users in producing specific objects, such as 3D-printed jewelry, lamps, games, or robotics. The activities mostly have no formal requirements for participation and allow users to drop in as they wish. Normally, the activities do not have a strong temporal structure. Instead, they are structured around selected tools and materials and a pre-set objective (e.g., to produce a lamp). After a brief introduction to the selected tools and materials, the activities depend on the users' curiosity and readiness to engage themselves: *"You get a brief introduction and thereafter you play with it yourself. In these activities, it is play and curiosity that drive it*" (L3). For example, the users build ball mazes, test the air resistance of objects in a wind tunnel, or participate in Hebocon competitions. Hebocon is mentioned by several practitioners. It consists of building a robot with a battery pack, a hobby motor, and materials such as cardboard, garbage, or old toys. The object-driven activities are designed to trigger engagement. One practitioner argues that the activity centers around "*a quick experience of success that makes you want to build more*" (L11), while another stresses the social connection between parent and child: "*What often happens is that the children are engaged in the beginning and, at some point, everything takes a turn toward - you can build yours and dad will build his. It's so funny (laughs)*" (L8). Though the collaboration sometimes breaks down, it is in most cases an engaging, social, and collaborative activity in which the parent scaffolds the child's activities.

In contrast, the tool-driven scaffolding approach is less about the produced object and more about building technical skills. For example, one library divides their activities between object-driven activities and "*Go to tech"* activities, which are tool-driven. Go-to-tech is *"an activity where you sign up for a trajectory that runs over a period, sometimes four sessions. It was organized on Thursdays and you learned to 3D-print, use the folie cutter, or something else"* (L6). In some makerspaces, the tool-driven activities are a means for adults to become certified in operating the machinery in the makerspace. However, 3D-printing is challenging to teach in an afternoon "[...] *simply because it is impossible. The technology is too slow*". Instead, the focus is on explaining the possibilities and limitations of the technology: "*Oftentimes, people have unrealistic expectations about what these 3D-*

printers can do. It is about killing those ideas [...] So it is mostly about communication" (L13). These workshops introduce technologies in the makerspace and provide a background for engaging in conversations about them.

The benefits of non-formal activities are that they ensure low barriers of entry by taking place in a limited period of time, having no formal requirements for participation, and being confined to the tools and materials made available. These conditions can spark interest in the tools and methods in the makerspace and build initial competences for subsequent informal uses of the makerspace. Nonetheless, as one practitioner argues, "*There is not much process in it*" (L8). The brief duration of the non-formal activities allows little room for exploration, tinkering, and creativity. Some libraries try to circumvent this barrier by lending toolkits to users for exploration at home or by promoting the informal use of the makerspace. In that way, non-formal activities initiate engagement and serve as scaffolds for subsequent informal uses of the tools – in the makerspace or at home.

4.3 Informal Learning Activities

The informal makerspace activities are unsupervised. During these activities, the makerspace tools are used for self-directed projects. To participate in informal activities, the users must be able to develop ideas and operate the tools. In addition, they must comply with the formal rules of the makerspace, such as the limitation to "*make prototypes only*" (L4) and the payment for materials. Informal activities unfold in self-driven and community-driven ways.

The self-driven activities are uses of the tools in the makerspace with the objective of making individually defined objects. Some libraries scaffold these activities by requiring that users schedule their use through a booking system, which makes it possible for the practitioner to schedule time for helping users to get started. In one makerspace, the self-directed activities included a "*mother making wall stickers for her children's room*", "*a graphic designer printing a large-scale poster*", "*a family making textile prints*", "*a man making t-shirts for himself and his friend to wear at their motorcycle club*", and "*two girls decorating t-shirts for a school presentation on prejudice"* (L8). These activities show that the users, individually and in groups, use the makerspace tools to produce objects that satisfy their individual needs and desires.

Users in community-driven activities also work on their individual projects but in the presence of others. One practitioner, for instance, explains that they organize their activities around a weekly Open Lab: "*There are no learning objectives. People just show up with their projects and help each other"* (L5). In spite of the informal character of these activities, the practitioner stresses the importance of scaffolding them by providing help when needed: "*We prefer that there are at most six people but even with six people we are already dependent on them to help each other a bit. Sometimes there are too many and we can't help all of them"* (L5). In other words, new users need a great deal of support to understand the steps in the process, operate the tools, and adapt to the technical jargon. Compared to self-directed activities, community-driven activities provide opportunities for peers to help each other and for diverse users to meet: "*Cool situations started emerging, such as an elderly man helping some boys who were trying to repair a bike: 'Now, let me show you'. So, we have experienced educational situations and meetings between generations, ethnicities, and cultures around making"* (L9). In other words, users learn new skills while meeting diverse people in their local community.

The community-driven activities occur on a weekly basis, thereby providing continuity and an opportunity to build relations between the library and different users. For instance, one practitioner explains that they continuously scout for super users: "*We keep an open eye for people in the makerspace. If someone has a good technical level and understands the machines and is here often… When they show that they can help others and are willing to do so, then we ask them to become super* *users*” (L3). The super users have extended access to the makerspace but also share in the responsibility for including new users, passing on knowledge, encouraging others to share, maintaining the machinery, and developing the makerspace. In the makerspaces with strong communities, users plan field excursions and presentations for one another. Some makerspaces also serve preexisting groups in their community. For instance, Coding Pirates is an national NGO that organizes weekly gatherings for children and youngsters interested in coding. Here, the primary role of the library is to grant Coding Pirates access to the makerspace.

The informal activities provide conditions for users to conduct projects, meet others, share ideas, and develop social relations. But there are barriers to overcome. First, self-directedness is a challenge for some users. One practitioner argues: "*Not everyone can manage self-initiation and, if not, you don’t really fit in here”*. To participate in informal activities, users need to have an idea as well as to have the technical skills to use, or learn, the tools necessary to materialize their idea. Though makerspaces can help users get started, there often is little help for users who do not have a specific project in mind when they enter the informal space. Second, the communities can become homogeneous and, thereby, appear to be only for a particular group of people. For instance, one community consists primarily of elderly men and others primarily of children. One practitioner explains that community ownership and self-organization can happen at the expense of inclusion: *"It's really positive that someone takes ownership, but they must not feel that they own the place. We'd like to continue having open doors so everyone can feel they are welcome and that it's not a closed club*". That is, too much ownership by regular users may raise social barriers for new users. Additionally, he argues, it is the responsibility of the library to ensure that the communities are inclusive.

5 Discussion

There are four main results of this study. The first is the seven scaffolding approaches described in the previous section. The three others are challenges in scaffolding the learning in library makerspaces, namely that skill progression is poorly scaffolded, that multiple skills need scaffolding, and that communities appropriate spaces. In the following, we discuss these three challenges.

5.1 Limited scaffolds for skill progression

While the formal and non-formal activities in the makerspaces introduce users with few prerequisites to making, the informal activities provide a hub for communities of experienced users. In this way, the makerspaces scaffold activities for users at opposite ends of the learning spectrum – the novices who are addressed in short-term activities with accessible tools and materials [4,36] and the experts who are self-driven and rely on peer-to-peer assistance for support [21]. However, the makerspaces provide limited scaffolds for progressing from novice toward expert. After completing introductory courses or workshops, the novice users merely have unclear paths to follow and, thereby, limited possibilities for reaching deep levels of learning. These limited possibilities stand in contrast to statements about how makerspaces are a way to “*acquire 21st century skills*” [41], “*express creative and communal drive*” [18] and “*change the world*” [1].

We see three reasons for the limited scaffolding of skill progression. First, progression requires sustained commitment from the users. This commitment is difficult to foster, and the makerspaces have no activities that demand it because they struggle to engage users, including schools, for longer periods. Instead, the makerspaces do their best to ensure that their activities are accessible and fun for newcomers and discretionary users. In the absence of continued participation over longer periods of time, it is difficult for the makerspace practitioners to plan for progression. As a result, the practitioners succeed in providing low thresholds and high ceilings within the individual activity, but largely fail to scaffold learning and progression beyond the activity.

Second, none of the practitioners mention scaffolds that support users in defining projects or planning maker processes. On the contrary, the users are met with pluggable components and catalogues of exercises until they, suddenly, are met with the expectation of being self-driven in defining and managing their projects. The absence of scaffolds for defining and managing meaningful projects complicates the transition from the formal and non-formal activities to the informal activities. That is, it complicates the transition from the activities geared toward novice users to those geared toward experienced users. This complication is related to the 'keychain syndrome' [17], which denotes that it eventually becomes uninteresting for users to produce objects of little value and reproduce the same objects over again. If users do not see a path for expanding their learning and activities beyond such objects, they will lose interest in making.

Third, the skill-acquisition model by Dreyfus and Dreyfus [42] makes it apparent that different scaffolds are needed to facilitate progression in the users' learning depending on their current skill level. The five levels in the model have distinctive qualities that call for scaffolds specific to the levels. For example, the first three skill levels are analytic and call for scaffolds that conform with analytic thinking. At the novice level, this may include instruction and exercises. In contrast, the expert has an intuitive grasp of the problem; scaffolds that insist on analytic thinking will block users from reaching this level. In contrast to the five levels in the model, the makerspace practitioners appear simply to distinguish between novice and experienced users, thereby risking that the scaffolds fade too abruptly. In addition, a user likely has the multiple skills required for an activity to different extents. Such a mix of skill levels further complicates the task of providing relevant scaffolds.

5.2 Multiple skills need scaffolding

Making is a heterogeneous activity that requires multiple skills [17,19]. The scaffolding approaches aim to support users in acquiring this skill set, but they assign primacy to different skills by being community-driven, object-driven, project-driven, self-driven, tool-driven, or topic-driven. Hertzum [43] proposes a simple four-question method for supporting student designers. It gives emphasis to four skills by contending that design – and making – involves grappling with these four questions:

- What is the problem? And for whom?
- What technologies are available as building blocks?
- How can the change/design be accomplished?
- What is the solution?

Each question targets a different element of making. While the first question is about analysis, the second is about construction. The two last questions are about the process and vision elements of making, respectively. At the same time, the four questions are interrelated; answering any one of them also contributes to answering the others.

The formal and non-formal activities scaffold learning by freezing the answers to several of the four questions. For example, the formal, tool-driven scaffolding approach tends to specify what the problem is (e.g., you need a fancy wrist watch), which tools to use (e.g., a laser cutter), and what the solution is (e.g., a watch with a laser-cut frame). The users merely need to follow the instructions for how to make the watch. This approach is well-suited for novice users but mostly focuses on increasing their knowledge of available tools (the second question) and training their process skills (the third question). Within the formal and non-formal activities, it is only the project-driven scaffolding approach that relies on the users' analysis skills. The other approaches tend to specify what the problem is, and for whom, or to bypass this question by specifying up front what solution to make. The scaffolding of the informal activities is different. It does not pre-specify the answers to any of the four questions, except through the size of the tool package held by the makerspace. Specifically, the users in the self-driven activities are expected to have the necessary analysis and vision skills, while they can get some assistance with construction and process issues. In the community-driven scaffolding approach, most of this assistance is peer-to-peer guidance.

It is central to all the scaffolding approaches that assistance is available through interpersonal interactions with staff and peers. Prior makerspace research has shown that such interpersonal scaffolds help prompt critical reflection [23] and help users in persisting through frustration [24]. Conversations with instructors and peers may solve an immediate instrumental problem, but they also serve *"an internal mental function"* [24] in organizing thought. For example, non-formal activities for children and their parents rely on help from the parent, but also support the building of a common language between parent and child. Subsequently, this common language can scaffold other conversations about technology.

5.3 Communities appropriate spaces

Consistent with prior research [21], we find that interpersonal communication may create communities that appear closed to newcomers and, thus, constitute a barrier to entry. Closed communities are mainly a challenge in informal activities. The practitioners have a central role in ensuring that the communities stay inclusive and open to new users. At the same time, the makerspaces are eager to attract and sustain community-driven activities because they are more collaborative than the other makerspace activities. Relatedly, Katterfeldt et al. [44] find that maker kits with pluggable components help students conduct satisfying projects but also that the kits do not facilitate collaboration well. Sentance et al. [45] report similar challenges with implementing the micro:bit maker kit in education. While maker kits provide low barriers to entry, they have a distinct individual component; other scaffolds are needed to incorporate this component in a collaborative activity.

It is by meeting on a weekly basis that the communities provide the conditions for developing interpersonal relations and taking on challenging projects. Over time, the communities become more closely knit, better able to provide peer-to-peer assistance, and more valuable forums for socializing. In so doing, they also appropriate the space, for example through their increasingly implicit ways of interacting and their increasing sense of ownership of the space. Annett et al. [46] describe how community members, contrary to makerspace rules, stake claim to machinery by blocking it with their unfinished constructions, leaving their backpacks in front of it, or using other visual cues. These cues exemplify their desire to control the space and secure their access to the machinery.

In our data, it is apparent that a dedicated room (or multiple rooms) for the makerspace is a better scaffold for community-driven activities than an open space within the library. While an open space provides for better integration with other library activities, it discourages community-driven makerspace activities because it provides few possibilities for appropriating the space. For communities to form, it appears that they need a space they can turn into their place [47]. To scaffold community-driven activities, libraries must provide such a space and accept that it is a continual effort to balance community claims to the space against openness to newcomers.

5.4 Limitations

Two limitations should be remembered in interpreting and using the results of this study. First, the results reflect the Danish context in which the study is conducted. We contend that the study covers Danish library makerspaces well, but further work is required to establish whether the results generalize beyond the Danish context. Different results must especially be expected in countries where libraries have a different role in the local community, such as countries with different traditions for collaboration between libraries and schools. Second, this study analyzes makerspace practitioners' perspective on how they scaffold learning in library makerspaces. We acknowledge that the voices of the students and other users of the makerspaces are not included in this study. In our ongoing work, we shift the focus to the makerspace users to investigate how they experience and appropriate the provided scaffolds.

6 Conclusion

In this paper, we have examined how learning is scaffolded in library makerspaces. Through interviews with practitioners in fourteen libraries, we have examined scaffolds in formal educational activities, non-formal recreational events, and informal gatherings. The contribution of this paper is its analysis of seven scaffolding approaches and its discussion of three challenges that constrain the progression of learning. While makerspaces aim to support 21st century skills, creative expression, and change in the world, we find limitations in the scaffolds for realizing these objectives. The practitioners largely fail to scaffold the progression from novice toward higher skill levels, and they tend to scaffold the acquisition of technical skills rather than skills in defining meaningful projects. Finally, communities support sustained learning but struggle to balance community claims to the space against openness to newcomers.

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