

Article

Making Experts: The Boundary Crossing of Knowledge and the Emergence of Relational Expertise in a School Makerspace

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Abstract: Existing research has illuminated the multidimensional nature of knowledge creation in school makerspaces. Yet, limited research exists on the boundary crossing of knowledge in makerspaces and how it can lead to the emergence of relational expertise. Using video records of interactions between 10–13-year-old students and their teachers in a school makerspace, this ethnographic case study applied mediated discourse analysis to investigate the boundary crossing of knowledge and the emergence of relational expertise—i.e., engaging with one’s own expertise, while recognizing, responding to, and building on others’ expertise. The results demonstrate how relational expertise emerged through boundary crossing of knowledge, with increased opportunities for students to identify themselves as experts. The boundary crossing of knowledge was mediated by participating students and teachers as well as material objects, evidencing the social and material nature of relational expertise in the makerspace. By recognizing the makerspace as a boundary object and an epistemic tool, the study enhances current understanding of the boundary crossing of knowledge and the emergence of relational expertise within creative and digitally enhanced learning environments.

Keywords: relational expertise; makerspace; primary school; knowledge practices



Citation: Leskinen, J.; Kumpulainen, K.; Kajamaa, A. Making Experts: The Boundary Crossing of Knowledge and the Emergence of Relational Expertise in a School Makerspace. *Educ. Sci.* **2024**, *14*, 169. <https://doi.org/10.3390/educsci14020169>

Academic Editor: Lisa Bendixen

Received: 30 November 2023

Revised: 19 January 2024

Accepted: 3 February 2024

Published: 7 February 2024



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1. Introduction

Makerspaces have become increasingly popular in K-12 education, as they emphasize students’ interest-driven engagement in hands-on creative activities using novel digital tools [1–3]. Makerspaces are proposed to foster students’ agency, creative problem-solving skills, digital literacy, science, technology, engineering, and mathematics learning (STEM), and 21st century skills important for workforce development and overall functioning in contemporary knowledge society [4,5].

Several studies have reported school makerspaces as disrupting traditional educational boundaries, including those between the roles of teachers and students, and formal and informal knowledge (e.g., [6,7]). Research to date has also shown that school makerspaces can challenge dominant conceptions of what counts as valuable knowledge [8,9]. Knowledge across domains is typically appreciated in makerspaces and students have opportunities to apply their personal expertise embedded in various contexts while they pursue maker projects [6,10,11]. Hence, makerspaces are conducive to various sources of knowledge and expertise [12].

Despite existing knowledge, research to date has overlooked the mechanisms of the boundary crossing of knowledge and how relational expertise emerges in school makerspaces. Understanding how relational expertise emerges in makerspaces is important because relational expertise is known to support the embracing of different viewpoints and knowledge, and in turn promoting responsive action [13]. Additionally, relational expertise potentially leads to students’ increased engagement expanding their learning

opportunities [14]. Therefore, this socioculturally informed study generates knowledge on how the boundary crossing of knowledge takes place and how relational expertise is constructed into being in the interactions between students and their teachers in a school makerspace. Analyzing ethnographic video data of 4–6th grade students (10–13-year-olds) and their interactions with teachers in a school makerspace, we ask

- What characterizes the (re)sources of knowledge in a school makerspace?
- How does the boundary crossing of knowledge lead to relational expertise in the makerspace?

1.1. Theoretical Perspectives to Collective Knowledge Creation in Makerspaces

Collective knowledge creation in makerspaces requires a reliance on practices that are physically embodied rather than purely conceptual experiences [15]. This entails participants using a diverse range of digital and non-digital tools and artifacts, with language and materiality serving as a mediator for students' activities [16–19]. In turn, language and artifact-mediated knowledge creation channels participants' collective interactions and learning processes [15,20,21]. In materially rich makerspaces, addressing knowledge engages all the senses, including observation, touch, sensation, and listening [22]. This contributes to the development and utilization of various types of epistemic [i.e., knowledge] objects [9,23,24]. In these settings, the materialization of knowledge objects relies critically on various types of knowledge practices associated with the act of making [16].

In the realm of makerspaces, students actively participate in the design and creation of shared epistemic objects (i.e., knowledge objects) [25]. Emergent epistemic objects can be ideas, visions, and artifacts in making and are subject to negotiation and co-definition by the students, remaining open-ended in nature [15,25]. Working on shared epistemic objects creates opportunities for students to draw on diverse knowledge [16,26,27]. For instance, Becker and Jacobsen's study [28] showcased how to disrupt conventional boundaries in science education by providing elementary school students with opportunities to cross boundaries between the roles of student and scientist. This, in turn, enhanced their proficiency in scientific inquiry and expanded their scientific knowledge. Furthermore, a study conducted within an elementary and middle school setting showed how a story making project facilitated students transcending disciplinary boundaries between history, computer science, and the humanities [29]. Such integration of knowledge across domains not only bolstered students' collaboration and communication skills but also deepened their comprehension of technology and fostered their skills in using new technologies as a means of personal expression. Moreover, in a study within early years education, Marsh et al. [11] found that during making, children integrated knowledge from STEM and other disciplines by leveraging their existing knowledge about digital platforms, devices, and technologies. These children supported their peers and shared their expertise by crossing knowledge boundaries and disrupting traditional boundaries about who qualifies as an expert in early years education settings. Such boundary crossing of knowledge and expertise contributed to the establishment of a digital community of practice, subsequently nurturing the advancement of children's digital competence. Taken together, these studies demonstrate how the boundary crossing of knowledge during making can significantly enhance students' opportunities for deep and meaningful engagement in the creation of artifacts, thus benefiting their skills and knowledge across various domains [3].

Emphasizing collective creativity, the making process and its outcomes [such as epistemic objects] are not usually defined prior to the making activity [16,19]. Involvement in such collective, creative processes necessitates students cultivating a shared understanding of how different digital tools, tangible materials, and the workspace can contribute to the creation of emergent epistemic objects. This calls for students to negotiate their individual ideas and visions and monitor and leverage their own and each other's knowledge [6,25]. Moreover, during their participation, students need to apply their existing knowledge and take responsibility for their learning activities, for example, by coordinating joint work, exploring new ideas, and using the various resources available in the learning en-

vironment [30]. Existing research has also evidenced tensions in the boundary crossing of knowledge in school makerspaces. Such tensions can result from conflicting motives and demands of students and their teachers during collective activities [17,31,32]. Therefore, working across boundaries creates demands on students and teachers with consequences for the emergence of relational expertise.

1.2. Relational Expertise in a Makerspace Learning Environment

Based on the current body of literature on collective knowledge creation in makerspaces, in this study, we posit that the boundary crossing of knowledge can lead to the emergence of relational expertise, which we consider to be a form of knowledge practice. In essence, knowledge practices, also known as epistemic practices, involve discursively and materially mediated knowledge [33]. Specifically, we hold that solving problems during making, and pursuing novelty requires one's engagement in shared knowledge creation practices [15]. Pursuit of novelty can result in new, transformed knowledge practices, such as relational expertise [34].

We rely on Edward's [13] concept of relational expertise, defined as "confident engagement with the knowledge that underpins one's own specialist practice, as well as a capacity to recognise and respond to what others might offer in local systems of distributed expertise" [13] (p. 33). This knowledge practice emerges through students' and teachers' discursively and materially mediated social interaction which occurs at the boundaries of diverse knowledge and knowledge practices [13]. We posit that boundary crossing knowledge provides a foundation for relational expertise. In turn, we understand expertise as a high level of competence and deep understanding of a particular domain. Departing from cognitivist views of treating expertise as an individual's personal competence, we understand expertise as a collective construction, mediated via boundary crossing and through shared knowledge practices, requiring the synchronous attention of multiple individuals (see [13,20]).

Informed by existing research on students' collective knowledge creation in makerspaces, in this study, we explore how students integrate knowledge in their maker activities and how this integration, i.e., boundary crossing of knowledge, potentially leads to the emergence of relational expertise in a primary school makerspace. As most previous studies relied on short-term interventions [3], this ethnographic case adds to existing research by investigating how boundary crossing of knowledge emerges in the interactions between primary-school-aged students and their teachers in a makerspace over time. Furthermore, by analyzing relational expertise as a social and cultural practice, our study extends current knowledge by demonstrating how the emergence of relational expertise within a school makerspace can either reproduce or challenge the existing norms of participation and interaction within a formal school context. Overall, our study contributes to an expanded understanding of the mechanisms involved in the boundary crossing of knowledge and relational expertise within school makerspaces and other similar technologically and materially rich creative learning environments.

1.3. Study Overview

This research is grounded on an ethnographic case study in a school makerspace called the FUSE Studio. We consider the ethnographic case study approach to be methodologically well-suited to producing knowledge about the boundary crossing of knowledge and the emergence of relational expertise in a makerspace context [35,36]. Moreover, applying sociocultural theorizing, our methodological approach focuses on discursive and tool-mediated interactions between individuals and their social context (see e.g., [37–39]).

The empirical context of this study is a city-run primary school located in the capital area of Finland. As a response to the new national core curriculum requirements, the school introduced the FUSE Studio (see www.fusestudio.net) as one of its elective courses. The FUSE Studio is an infrastructure of learning that combines digital tools (e.g., computers, 3D printers) and tangible materials (e.g., foam rubber, electronics, textiles). In the FUSE Studio,

students are free to select which projects to pursue and with whom. Figure 1 displays a student interface (view) of the FUSE projects on a computer screen. Figure 2 depicts students actively working on various projects in the FUSE Studio makerspace. Our primary data comprised 23 h of video recordings and the field notes of 10–13-year-old students (N = 94) and their teachers carrying out making activities in the FUSE Studio, collected during an academic semester—that is, from the beginning of January until the end of May.

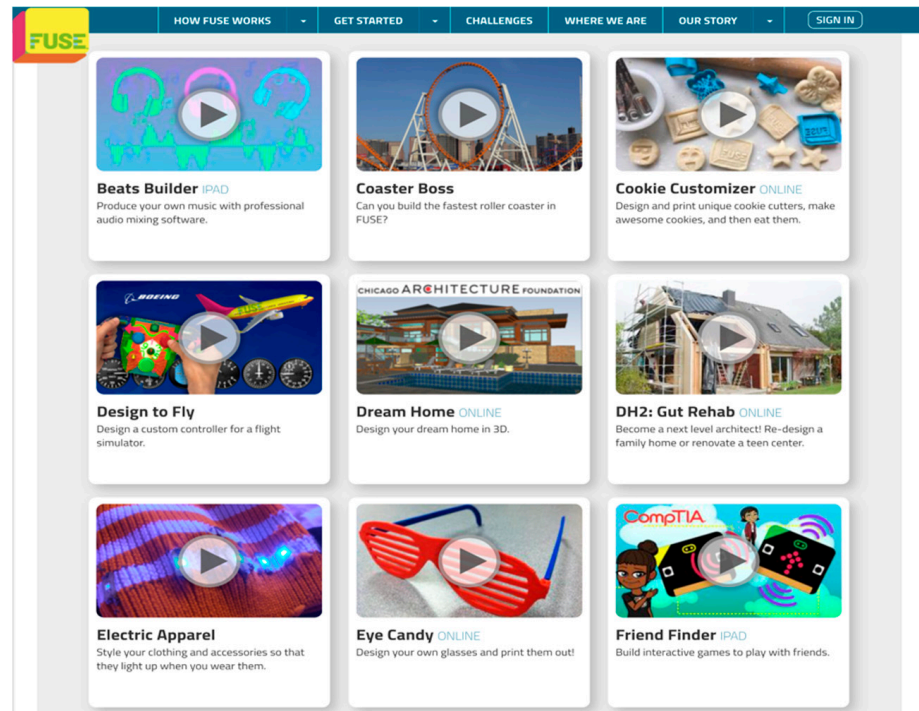


Figure 1. A screenshot of the student view of the FUSE Studio digital platform.



Figure 2. Students working in the FUSE Studio.

2. Analytical Procedure: Mediated Discourse Analysis

Our analytical procedure is premised on mediated discourse analysis (MDA) [40], which has proven to be a useful tool in analyzing collective knowledge creation while creating multimodal artifacts [41,42]. For our study, MDA provides a means by which to analyze the boundary crossing of knowledge and relational expertise as mediated by several modalities, namely, discourse, tools and materials, and embodied actions [16]. To note, in our analysis, we also paid attention to the learning context and the mediational means (i.e., tools and materials, talk, actions) used by the participants [40]. Furthermore, we employed a sociocultural understanding of ‘learning context’ as constituting cultural and historical dimensions that frame what one is expected or entitled to do [37,38] and understanding contexts as mediated by individual interests, prior experiences, and what counts as valuable knowledge [8,9,43].

We began the analysis by viewing the entire video data corpus to locate interactional events in which we could observe the participants integrating knowledge across resources and modalities. Hence, we employed an understanding of communicative modes [44], to track events in which the participants directed their proximity and body posture to create a shared space in which knowledge was negotiated and integrated. This phase of analysis produced 61 events that we selected for a detailed, mediated discourse analysis [40]. The detailed analysis revealed that the boundary crossing of knowledge emerged during maker activities through participants *identifying a student or a teacher as an expert, resourceful use of the FUSE Studio platform, collaborating with student experts, connecting with external experts, and debugging with technology*.

To answer our second research question, *how does relational expertise emerge in the makerspace?* we turned our attention to interactional events through which the participants engaged with their personal knowledge while recognizing and responding to others’ expertise in the FUSE Studio [13]. For this, we applied a typology of knowledge practices created in our previous study [16], namely, *orienting to knowledge, interpreting knowledge, concretizing knowledge, expanding knowledge*. *Orienting to knowledge* refers to discourse and embodied actions during which students identify relevant knowledge resources, both human and non-human, for engaging in and executing maker activities. *Interpreting knowledge* refers to sharing and exchanging existing knowledge and experiences in relation to the task, tools, and materials. *Concretizing knowledge* involves externalizing knowledge creation into knowledge objects and tangible artifacts. The process of concretizing knowledge can include joint searching for solutions, negotiation, adjustment, agreement, and elaboration of existing ideas. *Expanding knowledge* refers to critical engagement in modifying or revising epistemic objects, resulting in expanded understanding of the situation and an improved knowledge object or artifact.

3. Results

Our findings show that the FUSE Studio learning environment posed multidimensional demands on teachers and students to negotiate and integrate knowledge during their making projects. These negotiations were necessary for developing a shared understanding of the situation and maker activities. Our results point to the fact that integrating knowledge from various sources demanded collective efforts both from the students and their teachers. Specifically, the participants’ collective engagement in shared knowledge practices led to identifying, coordinating, reflecting on, and transforming boundaries in the makerspace environment. Consequently, such collective processes disrupted traditional boundaries of who counts as an expert, by expanding the students’ opportunities to become positioned as experts, contributing to the emergence of their relational expertise.

Next, we discuss details of the emergent process of relational expertise. We do this by using selected empirical examples which depict how boundary crossing of knowledge took place in the makerspace and how it gave rise to the emergence of the participants’ relational expertise.

Orienting to and interpreting knowledge during making

Our analysis reveals how orienting to and interpreting knowledge are important mechanisms of boundary crossing and conducive to the emergence of relational expertise in a makerspace context. In the following vignette, drawn from our empirical data, we illustrate how the students' oriented to and interpreted knowledge during their maker activities and how these practices evidenced the boundary crossing of knowledge and led to the emergence of relational expertise.

The students, Alma and Olivia, were both 5th grade students working in the FUSE Studio makerspace. Looking at the data across the academic year, we noticed that Alma persevered in her projects, working on the same projects, week after week. Preceding the interaction presented in Table 1, the teacher and Alma jointly oriented to the problem and to the sources of knowledge available to them. Alma had been working on a necklace using 3D design software and wished to print her project with a 3D printer. However, she ran into technical difficulties and worked with the teacher to overcome these:

Table 1. The teacher and Alma orienting to and interpreting knowledge.

(1)	T:	Alma, do you know how to activate the entire design?
(2)	Alma:	(works on the necklace model, then turns to instructions she accessed through the FUSE Studio website)
(3)	T:	It could be that once you activate the entire design, the 'export' option will appear. Or at least I found one tutorial that indicated that could work.
(4)	Alma:	(Surfs the FUSE Studio platform and project instructions)
(5)	T:	(Remains standing at a small distance, carefully watching what Alma is doing)
(6)	T:	Could it be in that video? (points to the screen)
(7)	Alma:	(opens the video tutorial)
(8)	T:	Ok, now it's clicked like that.
(9)	Alma:	Is it there? (Points to the screen)
(10)	T:	Ok, now it's there.
(11)	Alma:	The STL is here. (Points to the screen)
(12)	T:	The thing to be exported should somehow get activated.
(13)	Alma:	See, now he (the instructor on video) clicked it.
(14)	T:	Yeah.
(15)	Alma:	Hey! I might know why it (the design) wasn't activated!
(16)	Alma:	(Closes the tutorial and opens the design window)
(17)	Alma:	This activates the pieces separately.
(18)	T:	Right, yeah. How could it be activated as a whole?
(19)	Alma:	I need to see if—wait—I'll see if I can open this other file.
(20)	T:	It looks like it works now.

As illustrated in Figure 3, the participants' joint attention is manifested in their proximity, gaze, and gestures, such as pointing at the screen. In this situation, the teacher granted Alma an expert position by inviting her to share her knowledge with the others.

In turn 1 (see Table 1), the teacher and Alma together made explicit the value of different sources of knowledge that could be drawn upon to overcome the challenge with the 3D design program. To coordinate the activity, the teacher first recognized Alma as an expert in the specific 3D design program. They then identified a video tutorial from a blog which could be used as an external knowledge source. All these practices realized through verbal (turns 1 & 2) and non-verbal (turns 4 & 5) actions evidence *resourceful use of the FUSE Studio platform, collaborating with student experts, and connecting with external experts*. Further, these practices enabled successful integration of knowledge and coordination of joint maker activity.



Figure 3. The teacher and Alma and orienting to knowledge as they collaborate to overcome a technical difficulty with a 3D design software.

In turns 3 and 4 of the vignette, the teacher and Alma identified a tutorial video and the FUSE Studio platform as additional sources of knowledge to be used in solving the maker challenge. During their collaborative interaction, the participants oriented themselves to knowledge through various resources, which enabled identifying and crossing boundaries of knowledge. Moreover, their interaction and shared use of tools also promoted their collective knowledge creation and the emergence of relational expertise.

Across the events analyzed, we also observed how orienting to knowledge was realized through *identifying the teacher as an expert*. In our view, this finding reflects the traditional idea of schooling, whereby the teacher is positioned as the knowledgeable expert, providing the necessary knowledge for students. Our study also shows that the teachers frequently reminded the students to turn to the FUSE Studio platform and its written instructions and video tutorials, in acquiring the knowledge necessary to pursue their maker projects. At times, the students reminded each other about the FUSE Studio platform as a source of knowledge. By doing so, the *resourceful use of the FUSE Studio platform* enabled the students to access expert knowledge (instructions and videos) and develop their own knowledge in their chosen project further.

Orienting to and interpreting knowledge during maker activities was also realized through *collaborating with student experts*. That is, it was quite common for the students to identify their peers as experts in each task. We interpret this observation as a manifestation of the so-called ‘maker mindset’, in which the students establish a collaborative orientation to making (see also [45]), turning to their peers as valuable sources of knowledge.

Our data also reveal the important role of *connecting with external experts* (such as through instructional videos in YouTube and/or expert blogs) and *debugging with technology* as means of orienting to knowledge in the makerspace. By *debugging with technology*, we refer to the students’ iteratively testing available digital and technical tools to advance their maker projects (see also [10]). We regard debugging as an important core feature of learning by making, in which knowledge is built not only in social interaction but also through hands-on, embodied interactions with digital tools and object tools [17].

Interpreting knowledge, particularly in relation to the tools and materials that were available was an important mechanism of boundary crossing and relational expertise in

the makerspace. Here, joint interaction and knowledge creation also enabled the students to identify themselves as experts in specific areas, such as in the use of a certain digital tool. In our view, the FUSE Studio functioned as a powerful boundary object, integrating diverse knowledge [46], and enabling boundary crossing of knowledge, coordination, and collaboration. Furthermore, the FUSE Studio as a boundary object began to provide common ground and a shared reference frame for the participants [47].

Concretizing knowledge during making

Concretizing knowledge during maker activities was an important mechanism of boundary crossing contributing to the emergence of relational expertise. This included the participants exploring alternative ways of working and solving problems as they negotiated and reflected on each other’s actions, perspectives, and knowledge. Such joint reflection expanded the students’ opportunities to act as experts, contributing to the emergence of relational expertise in the FUSE Studio. As was the case in the previous example, concretizing knowledge often occurred in quite subtle, non-verbal interaction. Our findings thus underscore that concretizing knowledge occurred within instances which involved the participants directing their attention, particularly through regulating their proximity and gaze in interaction across human and non-human resources.

The interaction presented in Table 2 occurred during the same FUSE Studio session as in the previous vignette. While the teacher and Alma worked on the technical issue with the 3D design program, another 5th grade student, Olivia, worked next to them on her own 3D design project, in which she designed a rabbit character to be used in an animation. Although Olivia’s project was different from the jewelry project Alma was working on, Olivia used the same software as Alma. Olivia watched a tutorial video on the FUSE Studio platform but could not fully understand the instructions and thus asked the teacher for help.

Table 2. The teacher, Alma, and Olivia concretizing knowledge during making.

(29)	Olivia:	What does this mean? (points to her screen)
(30)	T:	Now it says—I don’t know what happened previously in the video—but it says now that you can enlarge it (the character) and move it and so on.
(31)	Olivia:	(closes the tutorial video and opens her 3D model)
(32)	T:	(turns back to Alma’s screen)
(33)	Alma:	(keeps looking at Olivia’s screen)
(34)	T:	(takes control of Alma’s mouse and continues working on their technical issue)
(35)	Alma:	Can I see it? (Moves closer to Olivia)
(36)	Alma:	Click on the tale. Can you make that bigger? See, like this. (Moves to Olivia’s computer)

In this data vignette, in turn 29 (see Table 2), Olivia (sitting next to Alma in Figure 3) identified the teacher as an expert who could help her as she did not completely understand the video tutorial on the FUSE Studio platform. The teacher quickly summarized the main points of the video to Olivia and then turned back to Alma, to continue resolving the technical issue. However, instead of turning back to her own computer (see Table 2, turn 33), Alma continued to observe what Olivia was doing. Then, Alma reflected on the knowledge Olivia had gained from the tutorial video, integrating it into her personal knowledge, and intimated that she could help Olivia in her maker project. Although Alma and Olivia were working on two different projects, they used the same 3D design software in which Alma was previously identified as an expert. Therefore, by jointly reflecting on available knowledge about the software, namely, through *resourceful use of the FUSE Studio platform* and *connecting with student experts*, Alma and Olivia engaged in relational expertise as a knowledge practice. Their relational expertise further evolved as the teacher had, at this point, withdrawn from the activity, and Alma continued to assist Olivia in her maker project.

Expanding knowledge during making

Finally, as the students’ activity in the FUSE Studio evolved over time, the transformation of traditional boundaries related to schooling began to rise, strengthening the emergence of the participants’ *relational expertise*. In the empirical vignette, we previously illuminated how Alma and Olivia crossed boundaries between traditional teacher and student roles as knowledge holders and experts. At times, we witnessed the students’ and teachers’ interaction to lead to transforming these boundaries. Such interactional processes included novel ways of expanding knowledge, as the students and teachers jointly expanded their collective understanding of emergent and dynamic roles as learners, experts, and teachers in the FUSE Studio. Expanding knowledge and the co-occurring of the transformation of boundaries was particularly evidenced in situations during which the participants formed divergent collaborative groups, based on the students’ expertise, rather than based on their favored peer relationships. The expert positions were claimed through interactions through which the students acted as experts, guiding and assisting their peers in how to organize and conduct their making activities.

Preceding the empirical example presented in Table 3, the teacher had left Alma’s and Oliva’s table to help another student. After helping Olivia, Alma had moved back to her own computer and kept working on her 3D necklace model. Then, after working alone on her design for a while, Alma walked up to the teacher (see Figure 5):

Table 3. The teacher and Alma expanding knowledge during making.

(39)	Alma:	Hey, I know now how to activate the entire design (Figure 5).
(40)	T:	Great, how?
(41)	Alma:	You just need to draw a line around the entire design.
(42)	T:	Ok, great!
(43)	Alma:	I’ll test the other file as well.
(44)	T:	(Finishes giving instructions to the other student, after which walks back to Alma’s computer to see what she did, see Figure 4).

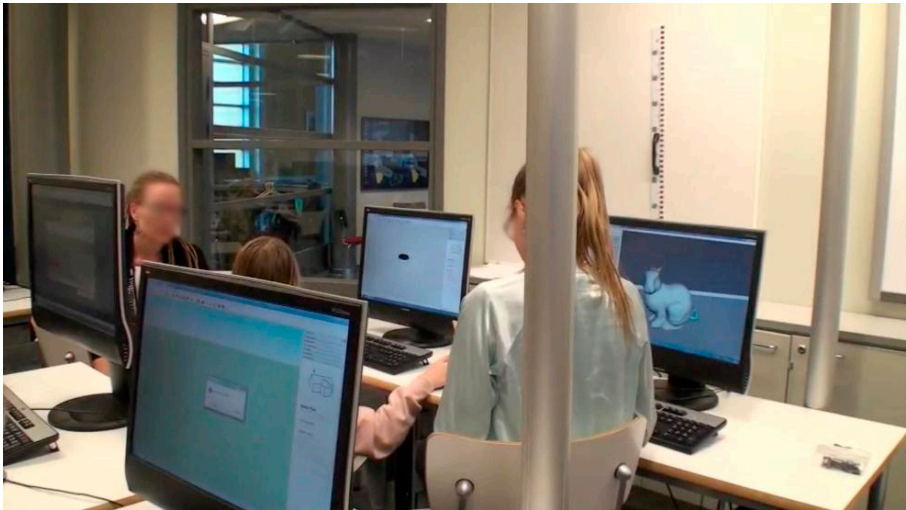


Figure 4. Alma and the teacher continuing to work as co-experts by gathering together in the FUSE Studio makerspace.

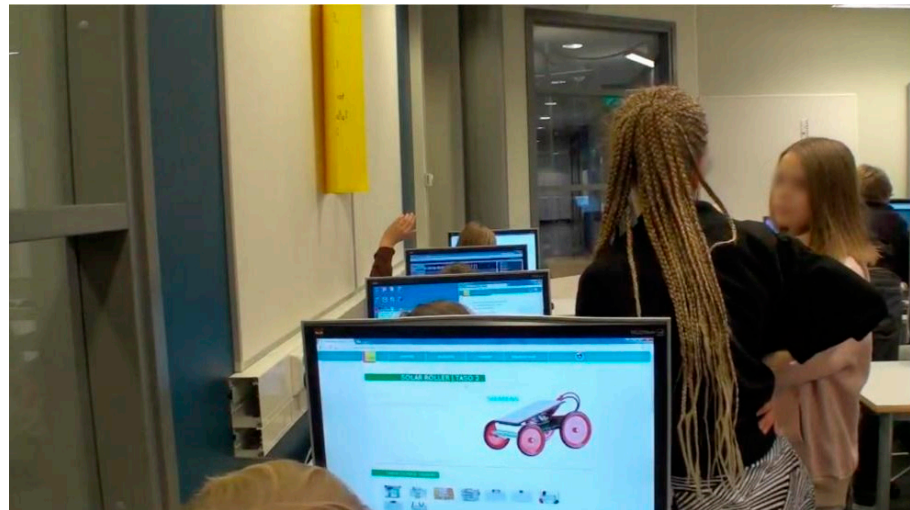


Figure 5. Alma and the teacher working as co-experts, creating shared knowledge about the 3D design software.

This vignette evidences the transformation of boundaries, as the teacher and Alma appeared not only as individual experts working in the makerspace, but also as co-experts, engaging in collective knowledge creation and relational expertise. This was particularly manifested in how they reciprocally shared, reflected on, and built on each other's knowledge in their verbal and non-verbal interaction, during which they repeatedly gathered to develop a joint understanding of the 3D design program [Table 3, turn 39; Figures 4 and 5]. In our view, this resembles co-teaching and co-learning practices that have also been reported in other studies in makerspace learning environments (see e.g., [48]). The collective transformation of boundaries further expanded the students' opportunities to act as experts, contributing to the emergence of their relational expertise in the FUSE Studio.

4. Discussion and Conclusions

This study illuminates how the boundary crossing of knowledge led to the emergence of relational expertise in a makerspace situated in a primary school. Figure 6 presents an overview of how relational expertise emerged in the FUSE Studio makerspace. This figure shows that the teachers' and students' joint interaction contributed to recognizing knowledge across sources. This recognition was a result of the participants' interaction during which the teachers' (T) and students' (S) prior knowledge as well as other resources (R) of knowledge construction were recognized and negotiated. The related interactions and boundary crossing of knowledge further contributed to the development of shared epistemic objects and thus facilitated students' learning through *identifying a student or a teacher as an expert, resourceful use of the FUSE Studio platform, collaborating with student experts, connecting with external experts, and debugging with technology*. Importantly, negotiation and integration of knowledge expanded the students' opportunities for collective knowledge creation and enabled the emergence of relational expertise. Relational expertise emerged through the participants' collective, discursive, and material practices, through which they evaluated their knowledge bases—i.e., how I know, what I know [33]. These knowledge practices entailed the students' seeking for knowledge that was absent or unknown by using various sources of knowledge, as exemplified in our empirical examples, and highlighted in Figure 6. Our results therefore underscore the learning potential associated with the emergence of relational expertise.

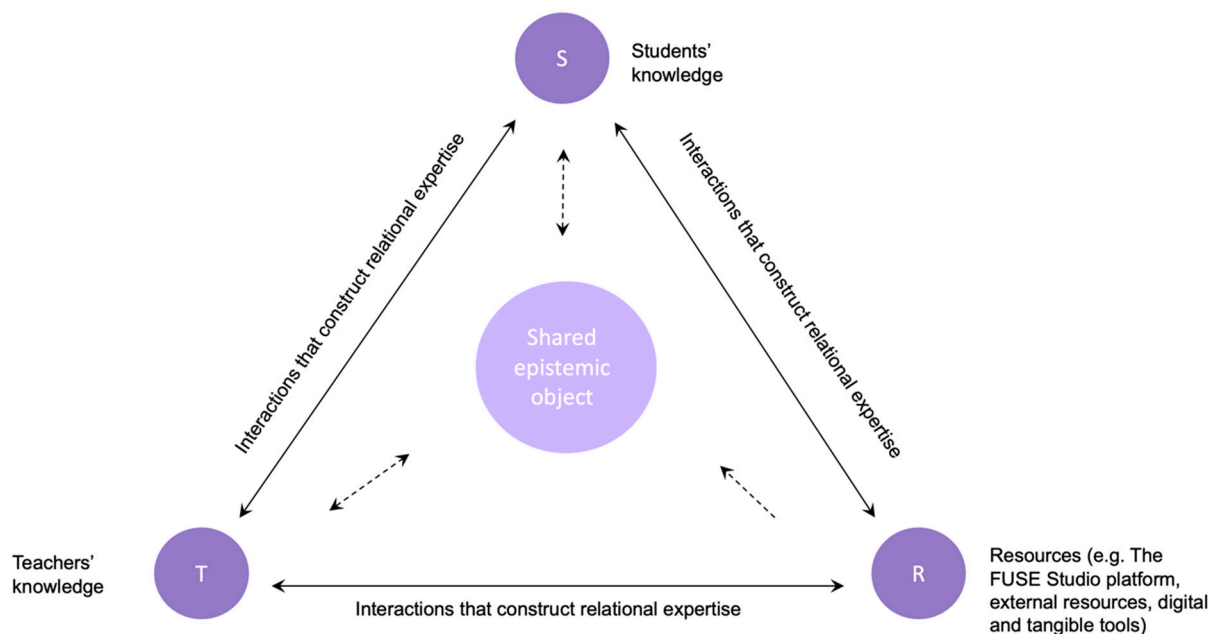


Figure 6. The emergent process of relational expertise.

This study illuminates how “expert students” emerged as a result of interactional processes that promoted recognizing, responding to, and building on others’ expertise. Moreover, the study sheds light on the teachers’ role, which ranged from an expert to a novice, because teachers recognized and responded to the students’ knowledge and vice versa. In addition, our study points to the importance of recognizing students’ and teachers’ personal orientations to knowledge creation as they play a role in the emergence of relational expertise.

The results show how relational expertise was mediated by multimodal means, namely, the participants’ discourse and the material resources of the makerspace (see also [16]). Echoing previous studies, in our study, the participants’ knowledge creation was closely linked with their joint activity of making [9,23,24]. The FUSE Studio makerspace, together with the participants’ interactions, supported the students in integrating knowledge from several sources, by utilizing the teachers’ and students’ knowledge as well as the other knowledge resources available to them (see Figure 6). The FUSE Studio makerspace environment thus created a space for the students and teachers to share and create knowledge (see also [49]). Over time, the FUSE Studio makerspace came to function as a boundary object [46,47], or as an epistemic tool [33], that invited the students and teachers to externalize their knowledge. Moreover, the FUSE Studio as a boundary object brought together the intersecting but sometimes conflicting knowledge practices of student-led making and teacher-led schooling. The makerspace environment encouraged the participants to move between novice and expert positions, enhancing the emergence of relational expertise (see also [50]).

Previous research has stressed that relational expertise can support openness to others’ perspectives and knowledge, mediating responsive action [13]. Moreover, relational expertise can provide expanded opportunities for students’ participation and learning [14]. A more nuanced understanding of the emergence of relational expertise can broaden students’ democratic access to making and deepen diverse student participation in makerspaces (see also [51]). Hence, it is important that emergent relational expertise—accounting for teachers’ and students’ knowledge and expertise—is considered when designing school makerspaces and in supporting their educational objectives, such as inclusivity.

Although our study makes an important contribution to the current understanding of boundary crossing of knowledge and the emergence of relational expertise within a formal school makerspace, we acknowledge the presence of limitations that necessitate careful

consideration. Our analysis is subjected to our own interpretations, and interpretations may always be otherwise. Although this study is limited to a specific makerspace, the FUSE Studio, we believe it enhances the current understanding of boundary crossing of knowledge and the emergence of relational expertise within creative and digitally enhanced learning environments, such as makerspaces. Moreover, understanding the FUSE Studio as a boundary object, or an epistemic tool [46,47], mediating the participants' interaction and the emergence of relational expertise, can aid the development of other types of boundary objects and epistemic tools. This in turn, can support students' and teachers' collective knowledge creation and relational expertise. Our study calls for future research to test our findings, to capture the boundary crossing of knowledge, knowledge practices, and relational expertise in makerspaces. Also, how relational expertise supports students' maker mindset and expert identities as individuals capable of designing and creating innovative products with technology deserves further research attention.

Author Contributions: Conceptualization, J.L., K.K. and A.K.; Methodology, J.L., K.K. and A.K.; Formal analysis, J.L.; Investigation, J.L.; Writing—original draft, J.L., K.K. and A.K.; Writing—review & editing, J.L., K.K. and A.K. All authors have read and agreed to the published version of the manuscript.

Funding: The research work of JL was funded by the SEDUCE Doctoral Program, University of Helsinki, Finland. The University of Helsinki also contributes to publishing in open access journals. The research project discussed in this article was funded by the Academy of Finland (project no: 310790, PI Kristiina Kumpulainen) entitled Learning by Making: The educational potential of school-based makerspaces for young learners' digital competencies (iMake).

Institutional Review Board Statement: The studies involving human participants were reviewed and approved by the Education Division of the City of Helsinki.

Informed Consent Statement: Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Data Availability Statement: The datasets presented in this article are not readily available because we do not have ethics approval to share the raw data from the current study as it consists of video data of children aged 7–12 years old. The study follows the ethical standards of scholarly research established by the Finnish Advisory Board on Research on Integrity (<https://www.tenk.fi>, accessed on 29 November 2023), Data Protection Act and the Convention on the Rights of the Child. Requests to access the datasets should be directed to kristiina.kumpulainen@ubc.ca.

Acknowledgments: Open access funding provided by University of Helsinki.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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