From Material Objects to Social Objects: Researching the Material-Dialogic Spaces of Joint Attention in a School-Based Makerspace

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Abstract: In this paper, we investigate the material-discursive spaces of joint attention between students and their teachers in a school-based makerspace. Drawing on sociocultural theorizing, Bakhtinian inspired notion of the "dialogic space", and material-discursive onto-epistemology, we introduce the concept of *social object* to explain how material objects can turn into joint attention and meaning-making in ongoing interaction. Video recordings (75 hours) of 94 students' aged 9 to 12 years old and their teachers' interactions in the makerspace were analyzed. The study shows how the material objects of the makerspace were enacted into social objects via joint attention *about* the objects, *around* the objects and *with* the objects. The study demonstrates the need to rethink the meaning and role of material objects in novel educational makerspaces for establishing and negotiating joint attention, mediating learning opportunities and tensions.

Keywords: social object, material-dialogic space, joint attention, educational, makerspace, engagement and learning

Introduction

Emerging digital technologies and infrastructures are changing educational practices with new possibilities and tensions for interaction and learning (Kumpulainen, Mikkola, & Rajala, 2018; Rasmussen & Ludvigsen, 2010; Säljö, 2010). Hence, continual investigation of how people interact with new cultural tools, the meanings they give to these tools, and how these new tools are hybridized with and across people, existing tools and practices is essential. In this paper, we focus on how tools, in specific, material objects of a novel educational makerspace are enacted in the material- discursive spaces of joint attention between students and their teachers. We argue, that at present, little attention has been directed to the meaning and role of material objects in mediating students' joint attention, engagement and learning in novel, material-rich educational makerspaces, encompassing the generative use of both traditional and more recent technologies, such as, 3D-printers, electronics, and design apps. Our study holds that that joint attention, that is, the human capacity to coordinate actions and attention with others on an object (Tomasello, 2000) is crucial for collaborative meaning-making and problem-solving, and it creates the foundation for social, cognitive and emotional learning (Bruner, 1995). It is hence important to generate new knowledge on the ways in which material objects of educational makerspaces can turn into joint attention in ongoing interaction with possibilities and tensions for students' engagement and learning.

Educational makerspaces prescribe a constructionist model of student-centered pedagogies in which students can work on personally meaningful Science, Technology, Engineering, Arts and Mathematics (STEAM) design projects, where they can make choices about their activities: simultaneously navigating through several fields of knowledge and using novel technologies that enable them to externalize, share and build ideas into concrete material objects (Halverson & Sheridan, 2014; Honey & Kanter, 2013; Peppler, Halverson, & Kafai, 2016). Emerging research around makerspaces suggests that they can foster students' creative problem-solving, STEM learning and 21st century skills, including digital literacy (see e.g. Honey & Kanter, 2013; Kafai, Fields, & Searle, 2014; Lindtner, 2014; Martinez & Stager, 2013). However, more research is deemed necessary to generate a more comprehensive understanding about the educational potential of makerspaces.

We know from earlier body of research that achieving and maintaining joint attention, collaboration and knowledge co-construction are important but demanding activities on their own right (Bruner, 1995; Ludvigsen, 2012). This complexity related to achieving and negotiating joint attention and meaning is likely to increase in educational makerspaces in which students work on complex interdisciplinary design challenges that encompass not only processes of creating specific material objects supported by a wide range of technologies and media, but also cognitive, emotional, relational and cultural processes surrounding the use and construction of material objects (Kumpulainen, Kajamaa, & Rajala, 2018). There are hence important insights to be gained from researching the material-dialogic spaces of joint attention between students and their teachers in educational makerspaces as to identify learning opportunities and tensions that can inform further educational design and support.

Conceptual background

Drawing on sociocultural theorising (Vygotsky, 1986, 1997), Bakhtinian inspired notion of the "dialogic space" (Wegerif, 2011), and material-discursive onto-epistemology (Barad, 2003, 2007), in this study, we introduce the concept of *social object* to explain how material objects can turn into joint attention and meaning-making in ongoing interaction in an educational makerspace. In our conceptualising, we do not automatically view material objects as social, but only then when they are integrated and taken up in the material-discursive activity. We consider social objects as transactional, facilitating joint attention and productive exchanges among those who encounter them (Knorr-Cetina, 1997; Simon, 2010).

Vygotsky and his co-investigators seminal sociocultural work on tool-mediation, widens our understanding of how humans, through tool-mediated activities, transform the environment in which they live (Vygotsky 1986; Vygotsky & Luria 1994). Vygotsky saw material-semiotic tools as constitutive of human activity and a prominent driving force for the development of human mind and culture (Vygotsky, 1986, 1997). For Vygotsky, language was the tool of tools, however, he did not undermine the mediational role of material objects (i.e. tangible tools and artefacts) for human learning and development. In fact, the centrality of materiality in human activity advocated by the sociocultural theories remind us of how social action and tangible and conceptual (signs and language) tools are intertwined (see also Ingold, 2010; Mäkitalo, 2011). Material objects are particularly important as they carry cultural knowledge both for the individual and collectives about their history, purpose and use, including values and ideologies. Furthermore, material objects can act as mediational means for personal and/or collective remembering (Cole, 1996; Wertsch, 2002), and enhance students' joint attention, engagement, learning and development (Wartofsky, 1979; Paavola et al., 2004; Kumpulainen, Kajamaa, & Rajala, 2018).

Sociocultural studies often refer to the Bakhtinian (1986) notion of a 'dialogic space' as a specific communicative event that evidences exploration, problematization and elaboration of diverse views and understanding in reasoned dialogue (Wegerif, 2011; Mercer et al., 2010). We extend this idea by introducing the notion of material-dialogic space. Following Hetherington & Wegerif (2018), we hold that a material-discursive emphasis can be used to extend the original dialogic account of the production of meaning in a way that it re-focuses attention on the multiple 'voices' of the material in co-mediating students' joint attention, engagement and learning. In the material-dialogic spaces, the material and discursive are seen as entangled and intra-acting, with phenomena performed as a result of ongoing intra-actions. Hence, the notion of intra-action underscores the mutually constitutive, entangled nature of matter and meaning (Barad, 2007). These intra-actions and performances generating from them, to which both people and materials contribute, co-create material-dialogic spaces with implications to ontological, epistemic, social, and ideological processes.

In this paper, we empirically investigate the material-dialogic spaces that constitute joint attention, engagement and learning between students and their teachers in an educational makerspace. To this end, we ask; How do material objects turn into and function as social objects in the material-dialogic spaces of joint attention? and How do social objects create opportunities and tensions for students' engagement and learning?

Empirical study

The empirical data stem from a city-run comprehensive school. The school follows the national core curriculum, which has been defined locally. The local curriculum of the school stresses design learning, which is considered to enhance students' creative problem-solving skills across the curriculum. The school strives for learner-centeredness and for innovations in learning and teaching as expressed in its local curriculum. As a response, the school has recently introduced a new educational makerspace, the FUSE Studio as part of its elective courses.

The FUSE Studio is an educational makerspace, 'a choice-based digital infrastructure for STEAM learning' (see Stevens & Jona, 2017). The technological infrastructure of the FUSE Studio offers students with different STEAM challenges that 'level up' in difficulty like video games. The challenges include Spaghetti Structures, Jewellery Designer, Robot Obstacle Course, Keychain Customiser, Electric Apparel, Coaster Boss and Solar Roller. The challenges are accompanied by various tools, such as computers, 3D printers and other materials (e.g., a foam rubber, a marble, tape and scissors), as well as instructions on how to process the challenges.

Each FUSE challenge is designed to engage students in different STEAM topics and skill sets. The challenges have been carefully structured to introduce students to new ideas and to support them through more complex iterations of those ideas. Students can choose, based on their own interests, which challenges they want to work on, when and with whom. They can choose to work alone, in pairs or in small groups. There is no formal grading or assessment by teachers. Instead, by using photos, video or other digital artefacts, students can document their completion of a challenge, and the completion unlocks the next challenge.

Altogether, 94 students aged 9-12 years old and their teachers (six male and two female teachers) took part in the study. Due to the elective nature of the course, the groups consisted of students from several classes.

Group 1 consisted of 32 students (22 boys and 10 girls), Group 2 consisted of 30 students (19 boys and 11 girls) and Group 3 consisted of 32 students (19 boys and 13 girls). Each group was supported by two to four teachers and teaching assistants. At the beginning of the autumn, each group had one 45-minute FUSE session a week. Later in the autumn, each session was extended to 60 minutes.

Methods

The primary data comprise 75 hours of video recordings of students carrying out design challenges in the FUSE Studio makerspace. The recordings were collected intermittently every week over a period of one semester by our team of researchers with four cameras in total. The episodes significant to our research focus in this paper, were transcribed and analyzed.

The video data were analysed using interaction analysis methods that took account of verbal, visual and material conduct in the students' and teachers' activity in the makerspace (Jordan & Henderson, 1995). The data were approached inductively by first approaching the video corpus as a whole and then focusing on selected events in greater depth (Derry et al., 2010). In particular, we were interested in those moments in the video data that gave evidence of the emergence of material-dialogic spaces of joint attention among the students and their teachers. Central to our analysis is a multi-step, multi-phase recursive analysis process, following the ethnographic logic of inquiry (Canstanheira, Green, & Dixon, 2009). For this, we watched the videos several times in an attempt to identify the regularities and patterns in the data source (Roth, 2005). Selecting interactional episodes evidencing the emergence and negotiation of joint attention (see also Gresalfi, Martin, Hand, & Greeno, 2009), we were able to trace how material objects turned into and began to function as social objects, mediating students' engagement and learning opportunities.

Major findings

Our findings reveal three distinct, yet often overlapping, interactional processes during which the material objects of the makerspace developed into social objects in the material-dialogic spaces of joint attention between the students and their teachers. Namely, the study shows how the material objects of the makerspace were turned into social objects via joint attention and social interaction *about* the objects, *around* the objects and *with* the objects. We shall illuminate these three dominant manifestations of social objects in the vignettes below. These vignettes also make visible how the material dialogic spaces of joint attention created opportunities and tensions for students' engagement and learning in the makerspace.

Vignette 1: Hey, what's this 'hole thing'?

This vignette illuminates a material-dialogic space of joint attention in which the students are wondering and experimenting about the use and functioning of a FUSE Studio design software, supported by the teacher. The vignette demonstrates the students' sense-making about the material objects in the educational makerspace. Here, it becomes clear how engagement with and learning to use the advanced technological tools of the FUSE Studio makerspace is pivotal for gaining access and authority in making activities in this space.

1. Student 1/Mel: Hey, what is this hole thing?

2. Teacher: What thing?

3. Student 1/Mel: Hole. That hole.

4. Teacher: Yeah you're supposed to make a hole there.

5. Student 1/Mel: What hole?

6. Teacher: Or what?

7. Student 1/Mel: No, I mean what is that hole?

8. Student 2/Anne: Yeah, what does it do?

9. Teacher: Is it that it turns transparent for a while so you can… Click on it again so it goes into the hole-mode. [girl clicks]

10. Teacher: Yeah so it shows that you can, it turns transparent so you can see through it. If you have that kind of situation that your planning requires you to be able to look through it.

11. Student 1/Mel: What do we do now that we're ready?

12. Student 2/Anne: We should probably look at the video.

13. Teacher: Look at the directions, I can't remember by heart.

14. Student 1/Mel: You're guiding it now Anne, I can't be using that thing [the laptop] the whole time.

15. Student 2/Anne: Okay. So, let's continue. [clicks open the directions video on the website]

16. Student 1/Mel: This is so slow… We have done that already.

17. Student 2/Anne: Okay, new video. [girls continue watching, teacher leaves]

In this example, two girls are sharing a laptop and working together on a design challenge the Keychain Customizer. They are designing a model of a keychain but are unsure of the software Tinkercad's commands. For that reason, they ask for the teacher's help. The teacher suggests that they try out the hole-command (line 9). He does not demonstrate using the command himself but encourages the students to do it. Then, the teacher explains what the command does and why one might use it (line 10). When the students ask what to do next, the teacher guides the students to look at the directions, like Anne suggests herself (12). By asking the students to do so, the teacher confirms a practice advocated by the educational makerspace that students should try to use other resources before asking for a teacher's help. Consequently, the material-dialogical space of the students' joint activity is expanded to involve the set of resources found in the website to support the students' independent engagement with the challenges and the associated technology. Therefore, the teacher points to the rules of the task and refocuses the students on it. This makes Mel assign the computer turn to Anne (line 14) who agrees (line 15). When Mel and Anne start looking for the directions, the teacher stays and listens to their discussion. When they are refocused on the task, the teacher leaves.
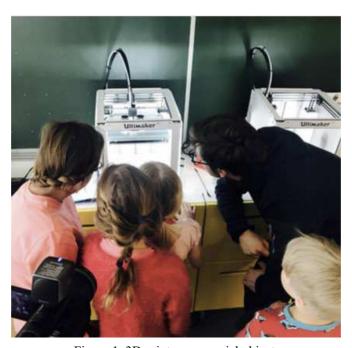
Vignette 2: The stickiness of social objects

Figure 1. 3D printer as a social object.

Our analysis of the data reveals that often times the social objects of the educational makerspace functioned as 'a glue' that brought the participants, both students and teachers, together *around* the material objects of the makerspace to jointly observe, wonder, discuss and/or share, as demonstrated by the above picture (see Figure 1). Often times, in these situations joint attention was achieved by gesture and other non-verbal modes of interaction. These material-discursive spaces were filled with silence and everyone intensively observing what was happening whilst the technology (such as 3D printer) or a human (a student or teacher) constructed or developed something with the material objects. We could also identify conversations about the matter and its meaning situated in the present, the students explaining what was happening or giving instructions about alternative ways of working or using other material objects than those available in the makerspace. Excitement and interests, and emotional

engagement in general were made visible by non-verbal and verbal communication in the material-dialogic spaces around social objects.

Vignette 3: Messing around with ones' own social objects

Our third vignette illuminates an alternative or, in fact, a competing material-dialogic space of joint attention constructed into being in the FUSE Studio makerspace *around* a material object. In this case, the student's own mobile phone. Here, the students are engaged in another activity they have found more meaningful instead of working on a FUSE design challenge. That is, they are playing around the Clash Royale game with their mobile phones.

[teacher walks into hallway to check on boys]

1. Student 1/Pekka: They're just playing...

2. Teacher Greg: Hey, what game do you have going on here?

3. Student 1/Pekka: They're playing Clash Royale...

4. Teacher Greg: Hey, put Clash Royale in your pocket and games away.

In this episode, the teacher walks into the hallway where a group of boys are working on a Coaster Boss design challenge. One of the students Pekka in the group responds immediately to the teacher's presence by explaining why their work is not coming along ("They are just playing", line 1). The teacher has a strong stance with his arms on his waist which can also be interpreted as a nonverbal sign of authority as he asks the students to stop playing the game. (line 4). The students obey the teacher's request and continue working on the FUSE design challenge. Overall, this example demonstrates the co-presence of at least two material-dialogic spaces that are performed in parallel, that is, working on the design challenge and playing the digital game. The co-presence of multiple material-dialogic spaces is enhanced by the fact that the online world and students' mobile phones are also commonly used in the FUSE Studio makerspace for the design challenge activities and their documentation. The teacher's actions in the vignette can be seen as an attempt to contain and constrain the dialogical-material space of the students' activity. However, it also demonstrates how digital tools define and alter the nature of the material dialogic space and the objects of joint attention.

Vignette 4: Making a Dream Home

Vignette 4 demonstrates how material objects intra-acted in the material-discursive spaces of joint attention as explicit mediational means to explain *with*. In this example, the students are working on a Dream Home design challenge.

1. Student 1/Tara: I would like to turn this, so I could get to the other side.

2. Student 2/Hanna: Me too, because I don't even know how to get there.

3. Teacher John: Well wait, let's see who is furthest along in Dream Home. Eric and Ian, have
you rotated the angles there, so you can get to the other side of the house?

4. Student 3/Rick: I have!

5. Teacher Greg: Hold down the mouse's button and then spin.

6. Teacher John: Okay, Rick can come instruct.

7. Student 3/Rick: [comes over to the girls] What?

8. Student 2/Hanna: How on earth do you turn this?

9. Teacher John: Hold down the mouse and…

10. Student 3/Rick: What did you want to do?

11. Student 1/Tara: Rotate the angle.

12. Student 3/Rick: Take that and then…[Tara rotates]

13. Teacher John: Which one was it Rick? Why don't you show me too.

14. Student 3/Rick: This tool.

15. Teacher John: Oh!

Here, Tara and Hanna have asked the teacher for help in rotating the view, so they could see the whole house. The teacher's first response is to find other students to help (line 3). By asking other students to help, the teacher is encouraging relative expertise in which the students can act as experts on the challenges. Student Rick is eager to help and comes over to advice the girls. After this, the teacher asks Rick to show him how to do it as well (line 13). By doing so, the teacher indicates that it is acceptable that teachers do not always know what to do in all of the challenges. He also reinforces Rick as an expert of the challenge. Interestingly, other teacher Greg exclaims the instructions in the middle of the conversation (line 5), even though he is helping other students at the time. Teacher Greg is probably aiming to speed the helping process, but this is in conflict with the other teacher's intervention strategy and that of the pedagogical model of the FUSE Studio makerspace that advocates for relative expertise. Teacher John does repeat these instructions partly (line 9) but then lets the student Rick to help and explain it to the two girls.

Conclusions and implications

Our findings that stem from our ongoing research work on an educational makerspace in a school context, make visible the nuanced ways in which the material objects of the educational makerspace were turned into and functioned as social objects in the interactions between and across the students and their teachers. Our findings reveal three distinct and overlapping interactional processes during which the material objects of the makerspace turned into social objects via joint attention and social interaction *about* the objects, *around* the objects and *with* the objects.

First, there were material-dialogic spaces in which joint attention was established via social interaction *about* the material objects themselves. This mode of joint attention in relating to material objects became evident especially when the habitual ways of engagement were disrupted, for example, by technological failures or discrepancy between means and ends of the activity (Kumpulainen, Rajala, & Kajamaa, in press). The problems in the technological infrastructure also created uncertainty among the teachers and challenged their role as authority as they did not always have control over the material objects themselves either. Secondly, we could also identify material- dialogic spaces in which joint attention was enacted and negotiated *around* the material objects. Our analysis suggests that the contemporary pedagogical and digital infrastructure engender dynamically shifting and expansive material-dialogic spaces that create new possibilities and tensions for students' engagement and learning opportunities. For example, the group configurations in the FUSE studio makerspace are flexible and the students are invited to work across groups to help each other. Similarly, digital tools offer vast possibilities for expanding the scope of the activity and dialogue (Kumpulainen, Mikkola, & Rajala, 2018). This imposes tensions for joint attention among students and between students and their teachers. Thirdly, we depicted material-dialogic spaces in which joint attention was established and maintained *with* the material objects. Here, the meaning potential of material objects in co-ordinating joint action and attention was pivotal. In all, it was in these sociomaterial and dialogic encounters that constituted the material-dialogic spaces of joint attention, when the material objects of the educational makerspace turned into social objects and mediated the students' engagement and learning opportunities.

The study reveals a dynamic interplay of multiple voices emerging in the material-dialogic spaces of joint attention. The inter-animation of voices that were performed into being in ongoing interactions evidence delicate and at times strong power relationships in the positioning of different voices, with consequences for engagement and learning opportunities. At times, the voices of material objects dominated the material-dialogic space of joint attention, and undermined the voices of others. At other times, it was the teacher's voice that become more authoritative from other voices, with opportunities and tensions for student-centered learning. We could also depict material-dialogic spaces that demonstrate joint reasoning and meaning making between the students and teachers, giving rise to relative expertise and enhancing the students' interest-driven creative activities and learning opportunities.

The results make visible how the material objects of the makerspace when turned into social objects of joint attention are important mediators of power and educational equity, making materiality a pivotal research focus for future studies in education. In our research not all the students were found to engage in interest-driven STEAM learning activities in the educational makerspace despite free choice of the design challenges they could work on. Our observations resonate with existing research that has pointed out how makerspaces hosted by various educational and cultural institutions often fail to attract and engage the broader population of young people in learning due to culturally biased materialities and activities (Barton, Tan & Greenberg, 2016; Peppler et al., 2016). Our research joins in with these concerns and calls for the quality and inclusivity of makerspaces and their materialities, and urges further investigation into novel, material rich educational spaces as they are related to creating democratic, equitable, and deep learning experiences for diverse student. Moreover, further research on

materiality is a pivotal research focus for future studies in education for promoting productive interaction in novel educational settings. In sum, the study demonstrates the need to rethink the meaning and role of material objects in novel educational makerspaces for establishing and negotiating joint attention, mediating learning opportunities and tensions.

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Acknowledgments