Collaborative Argumentation During a Making and Tinkering Afterschool Program With Squishy Circuits

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Abstract: This study investigates how young children engage in collaborative argumentation during Making and Tinkering (M&T) afterschool program using Squishy Circuits. Two perspectives guide the work: constructionism to explore M&T practices and everyday argumentation to explore the ways peers support each other in collaborative argumentation. The video-based study was conducted during an hour-long afterschool learning sessions over three weeks. Episodes of learners' collaborative argumentation practices were analyzed by examining talk, body formation, gestures, and tool handling. The findings expand current research on argumentation by describing and characterizing the collaborative argumentation practices that occurred during M&T. Findings also contribute an understanding of collaborative argumentation as a theoretical framework to expand constructionism.

Emerging research suggest that at a young age, children can engage in argumentation (Monteira & Jiménez-Aleixandre, 2016; Siry, Ziegler, & Max, 2012). Young children's argumentation includes purposeful observation (Monteira & Jiménez-Aleixandre, 2016), evidence construction, and theory formulation (Manz, 2016). Most science education argumentation findings are from classroom contexts where teacher support is available; less is known about argumentation practices in informal spaces with peer support. As such, our study focuses on collaborative argumentation practices during a Making and Tinkering (M&T) afterschool program by investigating the question: what are the ways that peers support each other in collaborative argumentation?

Theoretical framework: Constructionism and everyday argumentation

We use constructionism (Papert & Harel, 1991) as a lens to explore children's M&T activities. Constructionism builds on constructivism in which knowledge is not transmitted, but rather is constructed from personal experiences. Physical artifacts that are created and accessible during construction become "objects-to-think-with" to support learners to make connections as they build new knowledge (Kafai, 2006, p. 39). We seek to expand the theory of constructionism with the addition of a second lens, collaborative argumentation.

Collaborative argumentation is dialogical (Baker, 2002). Prior studies have highlighted the importance of collaborative sense-making (Zimmerman, Reeve, & Bell, 2010) as well as different social modes of co-construction and communicative approach that support or hinder the argumentation practices in science classrooms (Jiménez-Aleixandre, 2007; Weinberger & Fischer, 2006). Yet the field of education needs to know more about the manner in which learners engage in collaborative argumentation in out-of-school time settings. Bricker and Bell (2008) argue that research has failed to consider what everyday argumentation practices and competencies learners bring with them to new learning experiences. They have shown that youth's everyday argumentation shares great similarity to scientific argumentation practices. Building from an everyday perspective on argumentation, we seek to understand how children's collaborations in M&T are dialogically constructed through appropriation of their everyday practices and competencies.

Methodology

This study took place at an elementary school in the northeastern region of the United States. A 3-week afterschool program was developed around understanding the concept of circuitry using Squishy Circuits (Johnson & Thomas, 2010). Squishy Circuits includes LED lights, motors, buzzers, and a battery pack with two wires that can be connected to conductible Play-Doh™ to create a circuit. We chose to use Squishy Circuits because of its technological affordance to make the circuitry using Play-Doh™. We also provided iPads for small groups to collaborate with for their research and photo-documentation of the artifacts that they created.

Out of 48 children in the afterschool program, seven children who were interested in the topic consented to be in our study (8-9 years; 3 female). The two male children had previous experience with Squishy Circuits. The researchers were both observers and participants. The seven children were video-recorded for three weeks. Fieldnotes were taken during and after each session. Pictures of Squishy Circuit models and idea sketches were collected. Given that all modes of communication are used in argumentation, the analysis was guided by Goodwin (2007)'s embodied participation framework, paying particular attention to how argumentation is achieved through spatial and body formation as well as tool handling. Analysis followed methods of both conversation analysis (Ochs & Capps, 2009; Schegloff, 1991) and interaction analysis

(Erickson, 2004). First, content logs (Jordan & Henderson, 1995) were created and then analyzed along with ethnographic fieldnotes. Adopting Baker (2002)'s definition of argumentation as "cooperative explorations of a dialogical space of solutions" (p. 306), episodes were identified where groups faced a problem in relation to building their model with Squishy Circuits. Then, we identified episodes of collaborative argumentation where learners engaged in argumentation without the support from the facilitator. Most of the episodes of collaborative argumentation occurred for a short duration, except for those that occurred during the first week. We present one of the extended episodes here from a group of girls, Elina (8 years old) and Nicole (9 years old). Their case is representative of sustained collaborative argumentation in our dataset.

Findings

Our preliminary analysis illustrates that children in our dataset supported each other to engage in collaborative argumentation through collaborative meaning-making talk and role-taking.

Everyday language supported collaborative argumentation in M&T

The collaborative meaning-making talk was developed through the appropriation of everyday language. The excerpt below starts after Elina and Nicole engaged in a challenge to make one LED light up. They decided to make an alien with two illuminated eyes. Their plan to light two LEDs in one structure of Play-Doh™ was an impossible task without the use of insulating dough. As they continued to struggle, the researcher shared two principles: 1) a circuit needs two pieces of dough, and 2) the longer lead of the LED has to be connected to the dough that is connected with the red wire of the battery pack. The researcher shared the metaphor of LED having the "right shoes" to explain the concept of polarity and suggested flipping the LED when it does not light up. The episode presented below starts at Nicole and Elina's first attempt to light one LED after the circuitry principles had been explained by the facilitator.

01	Elina:	((to researcher)) Well this might work now, because I turned it around.
02	Researcher:	Right. Notice-
03	Nicole:	((looking at Elina and back to researcher)) But it has to be two different things.
04 05	Researcher:	Notice how… Right exactly. Nicole just said something really important. There has to be two different things. Two different pieces of Play-Doh™.
06	Elina:	((keeps looking down at her Play-Doh™))
07	Nicole:	((makes a little phone with Play-Doh™)) So this could be a phone for it.
08	Elina:	((looks up at researcher)) Oh! So it needs something for the alien.

After sharing of principles of circuitry, Nicole soon noticed that the problem with their model was due to only having one piece of Play-Doh™ (line 3). However, Nicole's explanation did not trigger any reaction from Elina. Elina was deeply engaged in making the model that she hardly glanced away from the Squishy Circuits model (line 6). What was a pivotal moment for Elina was to see that the alien model could now have a phone to act as a second piece of Play-Doh™ (line 8). This moment of realization was supported by Nicole's use of everyday making vocabulary such as "a phone for the alien" (line 7). The researcher had highlighted the importance of having a second piece of Play-Doh™. However, the scientific explanation of how circuits work did not cause any change of action from Elina until Nicole re-framed the scientific explanation in relation to their alien model. When a solution was offered in everyday language (not in scientific terms) — grounded to the features of their model — Elina understood the circuitry concept. This episode highlights the importance of children's everyday language in developing the collaborative meaning-making talk during argumentation in M&T.

Role-taking in support of developing a collaborative argumentation

Our analysis of the videorecords also showed that peers' role-taking supported them to initiate and sustain their engagement in collaborative argumentation. We found evidence that Nicole and Elina engaged differently in argumentation practices of identifying problems, offering solutions, and engaging in the trial-and-error spirit of M&T as they took on different roles. Findings showed that their different ways of engaging in argumentation influenced each another to create a model that was functional and also aesthetically pleasing. The excerpt presented below is a continuation of the previous from above.

01	Nicole:	How about a phone? ((brings the phone in front of Elina's face))
02 03	Elina:	Ok, a phone, hehe. But I am making it more exotic. ((pinches wire into the phone))
04	Nicole:	((turns the battery on)) Ok, let's just plug it in ((grabs the wire)). Wait and then

05		one, we only need one ((takes one LED out)), one eye ((puts LED to phone)).
06	Elina:	Oh, one eye, ok…That looks really weird.
07	Nicole:	We need it… ((brings the LED that is in the phone near to the alien to connect))
08 09	Elina:	No. I know we could make this the eyes and then we could make this the nose ((puts LED in as a nose and makes marks with fingers to create eyes)).
10	Nicole:	But we need this to stick into like... ((makes gestures))
11	Elina:	Look ((raises the model in the air))! There's the eyes and there's the nose!
12 13	Nicole:	((looks at the model)) And then one has to be in here ((points to the phone structure)) and one has to be in here ((points to the alien structure)).
14	Elina:	Like this? ((puts one LED lead to phone and the other lead to alien structure))
15	Nicole:	And then turn it on ((turns the battery pack on)).
16	Both:	((notice that LED light is not on))
17	Nicole:	Switch it around. Maybe it's in the wrong shoes.
18	Elina:	((switches the orientation of the wire))
19	Nicole:	((notices the light is still not on)) Maybe it's in the wrong spot ((shrugs)).
20	Elina:	((Puts LED near the alien's head where the other LED light is)) Nope ((nods)).

Throughout their collaboration, Nicole and Elina identified problems, offered solutions, and investigated by trial-and-error, but they did so by taking on different roles. Nicole acted in an engineer role when she suggested that her group explore functional solutions. Nicole's discourse and tool handling were aligned to the engineering design process: progressing from identifying the problem (not having two pieces of Play-Doh™) to offering a possible solution (a phone), to testing (plugging wires and turning on), to identifying a new problem (two LEDs in one Play-Doh™ piece), to finally offering an explanation to make sense of the scientific concepts with her partner (LED leads have to be plugged into separate pieces of Play-Doh™). Elina approached the task by acting in a designer role. Elina's discourse and tool handling related to making aesthetic refinements to the model (using the wires to make the phone exotic), noticing an aesthetically unpleasing element (not having two eyes), and suggesting an alternative design (LED could be the nose).

The girls' different ways of engaging in argumentation allowed them to recognize that the engineering and design roles were both needed to build a model that was functional and aesthetically pleasing. At first, Elina did not fully attend to the functionality of the model when Nicole made attempts to orient Elina's attention to the problem of having two LEDs in one Play-Doh™ (lines 4-5). After a few conversational turns, Elina began to incorporate Nicole's suggestions in terms of fixing the model to function (line 14, 18, 20). In this regard, Elina and Nicole's different roles supported them to sustain their engagement in collaborative argumentation.

Discussion

This study's findings expand the current conceptions of everyday argumentation by illustrating how objects-to-think-with (Kafai, 2006) such as Squishy Circuits allow young children to engage in collaborative argumentation using the interactional social processes of collaborative meaning-making talk and role-taking. The Squishy Circuits models supported these two girls (and others in our study) to understand the concept of circuitry. Importantly, the M&T tools as object-to-think-with acted as a concrete artifact from which the learners could generate evidence to inform their arguments about their design solutions. The visual and tactile feedback from the Squishy Circuits model supported Nicole and Elina to test out their ideas and identify errors in their physical models, allowing them to expand their understanding of circuity. In this regard, we posit that the role of physical objects in constructionism can be extended from objects-to-think-with into objects-to-argue-with. We posit that considering M&T as a rich context for engaging in argumentation can provide an additional rationale for bringing these M&T activities to formal and informal learning environments.

Our study showed that these two young girls had a capability to support each other through the use of everyday language and role-taking. Through their everyday language Elina and Nicole made connection to scientific concepts, which has been shown by the prior work to be an important skill in-school (Siry et al., 2012) and out-of-school (Zimmerman, Reeve, & Bell, 2008). Furthermore, Nicole's support of Elina, through her shifts in gaze and body formation can be seen as similar to the supports that adults use to bring the child share the same stance towards the activity (Goodwin, 2007). Also, through emergent role-taking Elina and Nicole recognized both the value of engineering and design roles in order to build a model that was functional and aesthetically pleasing. Different roles supported them to argue for different ways of doing things, which is in resonance with Papert and Harel (1991)'s idea of two styles that are relevant to constructionism: analytic formal style and bricolage style in which the work is organized through negotiation rather than planning. Consequently, our study's finding suggest that peers can support each other with their everyday language and role-taking during M&T in out-of-school settings as part of their collaborative argumentation. As such, we highlight the importance of making space for small group conversations using everyday language to allow children to collaboratively make sense of scientific concepts. Furthermore, we advocate for designing the M&T activity in a way that learners can equally address the functionality and the aesthetics.

Implications

Our findings illuminated that collaborative argumentation during M&T may be characterized differently from young children's argumentation practices in science. Argumentation practices in M&T were targeted to finding design solutions. This solution-focus influenced the nature of children's argumentation because it allowed learners to argue for multiple solutions. Consequently, learners used purposeful observation to identify problems in M&T rather than asking questions. Evidence construction was concerned with testing the functionality of a solution in M&T instead of justifying a scientific phenomenon. Collaborative argumentation in M&T led to creating solutions instead of formulating theories. These differences lead us to advocate for recognition of engineering argumentation. We will explore the nature of engineering argumentation in future M&T studies.

This study focused on investigating the ways peers supported each other to engage in collaborative argumentation during M&T. For future research, we hope to extend our analysis to investigate how and why such collaborative argumentation occurred by studying interaction within and across multiple peer groups. Furthermore, we advocate for future research to identify argumentation practices in other fields to inform the spectrum of argumentation practices that learners can engage in. This will support informal and formal educators, as well as researchers, to understand the different types of argumentation that may support learners' sense-making — expanding the idea of argumentation across disciplines and settings.

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