Towards a Stronger Conceptualization of the Maker Mindset: A Case Study of an Afterschool Program with Squishy Circuits

Short Paper[†]

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ABSTRACT

This study investigates the theoretical conception of the maker mindset in a making and tinkering afterschool program using Squishy Circuits. With a qualitative case study methodology, we analyzed the discourse and interaction of one learner guided by two analytical frameworks. Our finding shows the importance of providing making activities with various learning orientations (design, technology, collaboration, play) that challenge learners beyond their preferred engagement style to foster the development of all aspects of the maker mindset. Our finding highlights the need for a more nuanced analytical framework for characterizing how the three dimensions of a maker mindset interlock and diverge through making activities.[1]

CCS CONCEPTS

• **Social and professional topics** → **User characteristics**→ Age → Children

KEYWORDS

Squishy Circuits, Maker Mindset, Interest, Motivation, Self-Efficacy

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1 INTRODUCTION

Vygotsky [11] argues that creativity is a trait found in individuals, beginning from early childhood. In his view, all people have the potential to be creative in everyday life. In the past decade, researchers [3] have advocated for the potential of makerspaces to support learners as creative agents. Scholars [6, 10] studying makerspaces investigated activities, tools, materials, and interactions that support learners to engage in meaningful making in various formal and informal settings. Recently, scholars [9] have advocated for analytical frameworks that deepen our understanding of the learning practices and outcomes over time. In this paper, we explore the trajectory of a maker mindset development in an afterschool program using Squishy Circuits by brining two frameworks.

2 THEORETICAL PERSPECTIVES

A maker mindset, coined by Dougherty [2], refers to one's attitude to tolerate risk and failure and to engage in iterative experimental play to develop ideas into a reality. He describes that maker mindset can be developed so that learners have "the full capacity, creativity, and confidence to become agents of change in their personal lives and in their community" (p. 11). Other scholars [7] also describe it as the learners' interdisciplinary approach to facing challenges with curiosity, resilience, and collaboration. Ryan and colleagues [8] further assert that becoming a maker includes cognitive development and character development. This view emphasizes that becoming a maker needs a dispositional shift.

In this paper, we investigated the conception of the maker mindset via a qualitative case study. We adopted Chu and colleagues[1]'s definition of a maker mindset due to its grounding in empirical data. Their framework includes three attributes: 1) motivation (high initiative to engage in making), 2) interest (positive engagement in making), and 3) self-efficacy (positive expression of ability to make). In this analysis, we explore how various learning orientations during making activities relate to these three dimensions of a maker mindset.

To categorize learners' Squishy Circuits making activities, we adopted the Design Playshop model [12] that consists of four possible orientations towards making that children can take up: play, design, collaboration, and technology. A play orientation describes children's role-playing activities where they create meanings for their inventions or engagement during free play as "a temporary diversion" between creations (p. 93). A design orientation refers to emphasis on aesthetic decision-making. A collaborative orientation focuses on "shared knowledge production and distribution" (p. 93). A technology orientation emphasizes trial-and-error debugging. We adopted the Design Playshop model because it allows us to understand the conditions in which children's maker mindset develop.

By bringing the Maker Mindset [1] and the Design Playshop [12] frameworks together, we develop an analytical tool that examines the relationship between the learners' stances towards making as learners engage in making activities. This combined tool then allows researchers to understand how indicators of a maker mindset occur during making activities.

3 METHODOLOGY

3.1 Context and Setting

This study took place in 2016 within an afterschool program held at an elementary school in the northeastern United States. A 3-week afterschool program was developed with Squishy Circuits [4] that uses playdough, LEDs, motors, buzzers, and batteries. Seven of 48 children consented to be in our study (8-9 years; 3 female). A researcher designed and facilitated the program.

The goal was to learn the concept of circuitry through making with Squishy Circuits. The duration of the program was short to fully experience the ethos of making and develop a maker mindset, but we encouraged children to push beyond what they can do and engage in trial-and-error spirit of making. With this aim, we provided challenges with little instruction that were designed to scaffold children to understand circuitry concepts. We hoped that learners create "their own unique" model as opposed to following the instructions from the facilitator.

3.2 Data Collection and Analysis

The seven children were video-recorded with two stationary cameras as well as two head-mounted GoPro™ cameras (12 hours). Fieldnotes, pictures of Squishy Circuits models, and idea sketches were collected. Individual interviews were conducted on a week after the program ended.

Analysis followed two phases. In phase 1, content logs [5] were created for all video recordings. The stationary camera and GoPro™ video records were watched side-by-side to add descriptions to the content logs. Following ethnographic methods, the researchers' interest generated further questions related to phenomenon to explore across all learners. Questions emerged around one of the male participants, Koby. Koby showed interest and motivation towards building a Squishy Circuits model. However, when it came to making the model, Koby was hesitant to act independently and asked for his partner(s) to collaborate with him throughout the program. Given our research interest in maker mindset, Koby's case was strategically sampled as a case study.

Guided by Chu et al. [1]'s framework, we coded instances of Koby's utterances of self-efficacy, motivation, and interest (see Table 1). We also marked episodes in which Koby showed specific learning orientation (design, technology, play, collaboration). We paid particular attention to when Koby expressed interest, motivation, and self-efficacy. Hot spots [5] that illustrated Koby's shift in engagement were chosen for microanalysis. An interaction analysis [5] was conducted to explore Koby's engagement during making in relation to four learning orientations.

Table 1: Dimensions of the Maker Mindset [1]

Dimension	Definition	Examples
Self-efficacy	• Assess creation/self • Show knowledge of process • Successful tasks and debugging	I did it, Caleb! I know! The battery is not on.
Motivation	• Wanting to make, bring parts home, and add effects • Request more materials • Ask questions	Can I make now? I wanted to make the horn light up.
Interest	• Joy, enthusiasm, play	Yes, awesome! Look!

4 FINDINGS

Through the case study of Koby, our findings suggest that a learner's expressed interest, motivation, and self-efficacy are not linked; our case learner showed continued high interest, oscillating motivation, and a decrease in self-efficacy over time. Our work illustrates how the current conception of the maker mindset needs to be refined to show a fuller range of possible learner outcomes.

4.1 Koby's Maker Mindset Development

Koby continued to express positive interest and motivation toward making over time, however his approach towards making shifted to be less resilient. Frequency counts of three dimensions of the maker mindset in week 1 and 3 indicated this finding: interest (81, 14), motivation (62, 68), self-efficacy (32, 28). Despite these positive indicators, we did not find evidence that Koby developed the characteristics of a maker mindset. Findings illustrated that Koby showed lack of motivation to engage in iterative problem solving by week 3. We present episodes from week 1 and week 3 to illustrate this shift in Koby's engagement and attitude. The episode below occurred in week 1 when Koby wanted to build a unicorn with LED light inside the horn. This design needed structuring of conductive and insulating playdoughs in ways that would prevent a short circuit. This episode is Koby's third attempt in illuminating the LED inside the horn of the unicorn.

R: So I think what you need to do is put these insulating dough so that these ((points at the horn structure)) are separated.
K: So, do I put some of this right here?
R: Let's try.
K: Playdoh right here and right here and I wanna put some right here. ((adds insulating dough around the LED, nothing changes)) I don't know. I need another thing on top of it. ((adds more)) I wanna put a special twinkly thing. ((grabs yellow and puts it on top of insulating dough))
R: Let's see.
K: Now I need some more dough. ((puts green on top of yellow)) Let's see. ((grabs wires, plugs them in))
R: Remember the basic guidelines. ((grabs whiteboard)) It has to always meet these guidelines.
K: Ugggg... ((looks away from the board)) wait. ((frowns))
R: It doesn't work.
K: It's never gonna work.
R: It's gonna work!
K: This is just won't gonna happen.
R: I know you guys can all do it! You guys are all smart and creative, you can make it work!

When the researcher realized that Koby wanted to have the LED on the horn, she suggested separating the horn structure into two pieces (line 1-3). Koby added insulating dough on the horn, around the LED (line 6-8). When his attempt did not solve the problem, Koby added more playdough to make aesthetical refinements (line 9-11) and plugged in the wires at random places (line 14). The researcher directed his attention to the principles that they had written down to remind him that a circuit needs to form a circle in which LED leads are each connected to a separate piece of playdough (line 15-16). However, Koby did not incorporate the basic principles of circuitry (line 17), and instead expressed his feelings of frustration (line 19, 21). Given that this was his third attempt to create a complex design, this episode highlights Koby's iterative approach and persistence despite the unsuccessful outcome at the start of the program.

Over time, Koby's persistence through challenges decreased. We present two episodes from week 3 to illustrate his shift. The episode below starts at Koby's first attempt in debugging the circuit to illuminate the LED component for his cat model.

K: What? Wait, is it dead? Yeah, mine is dead.
K: Oh, wait! I didn't even put them in ((grabs battery wires and plugs them, but LED still does not light up)). Wait, is that thing dead?
K: ((changes the orientation of wire twice and makes sure LED is connected, LED does not light up)) What? This isn't working…ok, mine's dead.

Koby quickly reached the conclusion that his circuit would not work due to a low battery, without making any attempts to address the problem. He only tinkered momentarily (line 2-3, 5-6) and soon concluded that the battery was dead (line 7).

The next episode, which occurred a few minutes after the previous episode, also shows Koby' lack of persistence to fix the emerging problems in his circuitry model.

K: ((puts LED and sees the light is stronger than the first LED)) Oh, actually that's better. ((pushes LED into playdough, notices LED does not light up)) What? ((takes the first LED out and switches the battery on and off))
T: I think part of it was in the insulating dough.
K: Aggghhh! Agghhh! Aghhh! I am just gonna, I am just gonna give up. I am just gonna show him my anyway awesome parts.
T: Wait, I saw it working.
K: I know, but it doesn't… ((takes LEDs out, stops working, and runs to his friend)) Owen!

Koby originally planned to design a rainbow for his cat model. After Koby illuminated one LED, he added a second LED to check the color. Koby noticed that the second LED momentarily illuminated then lost its light when he pressed the LED into the playdough (line 2-3). Koby expressed his feelings of frustration (line 6) and decided to give up (line 7) even when Tyson prompted him to continue tinkering (line 5, 9). These episodes highlight that Koby did not always show the characteristics of the maker mindset. In this regard, our finding illuminated that the learner's expression of positive interest, motivation, and self-efficacy in making over time may not indicate the development of a maker mindset.

4.2 Koby's Shift Towards Design

Bringing the Design Playshop framework to analyze Koby's making activities showed that Koby's shift in attitude and engagement was related to his need to balance his interest, motivation, and self-efficacy in ways that supported him to move forward. We found evidence that there was unresolved tension between Koby's high motivation to create a complex design and low self-efficacy in circuitry knowledge, which influenced Koby to purposefully work on activities that capitalized on his design strengths (i.e., drawing, crafting). Our data showed that Koby preferred to engage in activities that foregrounded design (see Table 2). Koby did not exhibit the same level of positive interest, motivation, or self-efficacy towards making when activities foregrounded technology (see Table 3). This was also evident in Koby's engagement over three weeks. When challenges addressed circuitry concepts (i.e. all the possible ways to illuminate 5 LEDs), he expressed boredom and refused to participate (by waiting or engaging in free play). Instead, he continued to show motivation towards designing a model with playdough. However, as previous episodes illustrated, Koby was not able to create the model he envisioned because he did not fully understand the circuitry concepts. As such, Koby continued to experience tension between his high interest and motivation to engage in design-oriented activities and his low self-efficacy in completing technology-oriented activities.

Our analysis showed that Koby's low self-efficacy in technology influenced him to shift towards engaging in his preferred learning orientation (design) to capitalize on his strengths. During the first two weeks, Koby often expressed feelings of failure when he worked on circuitry aspects: "But I don't wanna fail.", "It didn't work the unicorn.", and "It's going to be super hard." In week 3, Koby deliberately stopped working on the unicorn (a complex task) in order to work on something else because he did not want to fail again: "I am probably try to make a unicorn it's not going to work. Just do this. ((starts drawing something else))." This change of design goal led him to make compliments on his own drawing ability and share what he created: "Best drawing ever", "Oh! Oh! I have something that's going to make all of you really…." "Guys, look! Look! ((show his drawing))" In this regard, Koby's shift towards design was a purposeful act, which reflected his need to reposition and increase his self-efficacy by working on a task that he could take control and move forward with.

Table 2: Maker Mindset in Four Orientations (week1)

Orientations	Interest	Moti-vation	Self-efficacy	Sum (%)
Design	34	35	12	81(53.7)
Technology	7	15	6	28 (18.5)
Collaboration	9	19	5	33 (21.8)
Play	1	7	1	9 (6.0)

Table 3: Maker Mindset in Four Orientations (week3)

Orientations	Interest	Moti-vation	Self-efficacy	Sum (%)
Design	9	54	26	89 (92.8)
Technology	0	7	0	7 (7.3)

5 DISCUSSION AND IMPLICATION

Our findings illuminate a weakness of the current analytical framework of the maker mindset by illustrating a case in which high interest and motivation in making can be tied with low self-efficacy in making. Given that tensions between dimensions of the maker mindset and learners' engagement styles (orientations) were found, more nuanced frameworks which can characterize not only the affect of leaners but also the activity systems of learners would support the understanding of the trajectory of the maker mindset development. We advocate for future studies to explore each dimension of the maker mindset with positive and negative indicators from the learners and also consider how they interlock and diverge with multi-faceted dimensions of making (i.e. design, technology, play, collaboration) over time. This will expand our understanding of the learners' pathways towards developing a maker mindset.

Our findings suggest the importance of supporting learners move beyond their preferred engagement style and adopt multiple learning orientations to develop the ability to tolerate and engage in iterative experimental play that may include failure (also called a maker mindset). As Koby shifted towards his preferred learning orientation, he did not have the opportunities to develop some of the positive characteristics of a maker (i.e., resilience, persistence), which is in resonance with prior findings on the learning outcomes of the participants who engaged in only one learning orientation [12]. We posit that if educators or designers provide various learning orientations for makers, this could strengthen the learning opportunities that making can provide. Consequently, this study points to the need for further theorization of constructionist learning environments and curricula that capitalize on making's potential to develop learners as creative agents [3]. Making experiences should not only provide learners with multiple entry points for activities, but should be designed to challenge learners to engage in new learning practices and activities.

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