Making the Maker: A Means-to-an-Ends Approach to Nurturing the Maker Mindset in Elementary-Aged Children

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Abstract

In this article, we present a new direction for the role of Making for children. Beyond the use of Making to teach specific STEM concepts as is common in prior work, we propose that Making activities should be designed with the focus of instilling a Maker mindset in children. Our target is elementary-school-level children aged 8 to 11. We present an approach that conceptualizes Making as a ‘Means-to-an-Ends’ to nurture a Maker mindset and identity in children. The approach was embodied in a carefully-designed storytelling Making kit called the Maker Theater, and two Maker workshops for children in the target age range. Our analysis goal in this article was to investigate how the potential for a Maker mindset/identity formation may be manifested in children’s attitudes and behaviors. Guided by a theoretical framework of three key determinants of the Maker mindset (self-efficacy, motivation and interest), we analyzed workshop data using qualitative coding methods to derive thematic indicators. We discuss our contributions and the value of our findings for the child-computer interaction community.

Keywords: Maker mindset; Making; Children; Storytelling; Electronics; Self-Identity; Evaluation.

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1. Introduction

The development of technologies such as 3D printing, open-source electronics, and accessible programming environments has given rise to a despecialization of aspects of prototyping and production so that broader populations can participate in ‘do-it-yourself’ (DIY) activities once reserved for technology experts. Collectively, these innovations and maturation of technology to support broader access have come to be called the “Maker Phenomenon”: a “growing community of hobbyists and professionals dedicated to making their own functional devices, whether it be technological gadgets, open source hardware and software, fashion apparel, home decorating, or nearly any other aspect of physical life” [1]. This phenomenon has spurred interest in the use of Making in educational settings to teach such STEM (Science, Technology, Engineering and Mathematics) curriculum content as science, engineering, electronics, robotics, and mathematics, and to encourage children to pursue STEM careers later in life. In this article, we argue that it is critical to see Making as a means to inculcate a ‘Maker’s mindset’ that has a far greater impact than the teaching of any specific subject matter at the elementary grade levels.

Taking a broader definition of Making as *the use of technological resources to build something of interest*, we see two vectors of differentiation between Making and the typical hands-on-learning activities (e.g., in science or art classes) currently employed within the existing structure of schools. First, the Making activity is infused with technology to differentiate Making from children making things (‘products’) through purely arts-and-craft activity. Second, typical hands-on classes focus on isolated ‘task completion’ or ‘worksheet’ activities that emphasize ‘product’, while Making is a continuous exploratory process that integrates both ‘process’ and ‘product’. We target Making for children at the elementary school level (grades 3-5) and propose approach that employs Making as a ‘Means-to-an-Ends’ – the thing being made and its utility becomes a pragmatic goal that sustains motivation, interest and engagement. We explore the approach through the design and use of the Maker Theater kit in two workshops with children.

2. Making in Children’s Education

Prior literature on the use of Making to support STEM education falls into four categories: **I. theoretical contributions**, such as analyses of the potential of Making and Maker technologies for education [2-5]; **II. practical initiatives** that organize Making activities aimed at children, e.g., the White House *Maker Corps* program and the *Young Makers* program that implement a community and school-based club model to connect adult mentors from the hobbyist Making community to interested youth [6]; **III. technical development** of Maker kits for children, e.g., *LightUp* [7], *littlebits* [8]; and **IV. empirical contributions** that assess either formally or informally effects of including Making in an educational setting, e.g., Flores and Springer [9] describe the assessment of self-directed learning that occurs in the Maker Space created at the Hillbrook Middle School to support their science curriculum. Posch and Fitzpatrick [10] report on case study experiences of children aged 10 to 14 years old attending a workshop at a FabLab that provided instruction on 2D and 3D design and fabrication, printed circuit board (PCB) fabrication and assembly, and software programming. Wanyiri and Ombatti [11] describe qualitatively the success of the FabLab Robotics Outreach Program (FROP) that introduced programming and

robotics to Kenyan girls aged 14 to 18 using MIT's Pico Cricket kit¹. The Fab@School study by Alexander, Tillman [12] studied the implementation of activities that integrated digital fabrication into math and science 4th- and 5th-grade classes with the help of pre-service teachers across two schools. However, their study focused on digital fabrication, defined as the process of translating a digital design into a physical object instead of just Making (manual construction). Their intervention activities included, for example, [creating] virtual 3D models, [constructing] those models into physical objects with cardstock and other materials, and [re-designing] their models based on initial testing. The study reported positive impacts on students' perceptions towards STEM.

Many of the theoretical contributions discuss the value of a Maker mindset but do not present empirical evidence. Most practical initiatives are not concerned with issues of research design. Technical contributions either do not have studies attached or have only informal or anecdotal reporting of effectiveness. Among empirical contributions, Alexander et al. [12], most relevantly to our research, assessed STEM perceptions that arguably influence mindset formation. Our observations relevant to this article based on our review of the literature thus are that presently: (i) Most significant Making initiatives for children are carried out at a practice level, and not as research projects; (ii) Research on the integration of Making with learning and education tends to emphasize the transmission of STEM knowledge and skills (i.e., science, math, computer science, electronics, etc.); and (iii) Studies with children in this area tend to focus on digital fabrication, rather than Making in the broader sense of the term.

3. The Maker Mindset and Self-Identity

Given the characteristics of Making, we argue that Making-oriented learning needs not be constrained to the assessment of specific skills and knowledge sets. We look beyond that to Making-based curriculum as the incubation of a Maker Mindset in children. In this section, we discuss how this mindset may lead children to form self-identities as individuals who may engage more broadly in STEM-related learning and activities.

3.1. The Maker Mindset: A Frame of Thinking

The idea of Making goes beyond a set of equipment, a specific method, a bounded place, or even a community of practitioners. It is a whole culture that celebrates certain key values of personal production and problem solving, a frame of thinking by which the Maker address problems by seeking 'do-it-yourself' solutions, a belief that they either have or can acquire the means to construct a solution, and possess a creative curiosity to seek solutions that the Maker can construct on her own. Martinez and Stager [13] describe Making as the "act of creation with new and familiar materials" where one takes control of their life and their learning. Martin and Dixon [14] describe how young people (ages 12 – 18) participating in a Maker club saw Making as 'transcending the barriers' of clearly identifiable Making activities at the club and being integrative with, and generalizable to their other life experiences that include problem solving and engaging in creative activities in school projects. The overarching goal of our research is to investigate how Making may influence self-perceptions by creating a Maker mindset, helping the child envision the idea that 'I am a Maker' as part of her self-identity and self-concept.

¹ <http://www.picocricket.com/>

3.2. Self-Efficacy, Motivation and Interest

We posit that the development of a Maker mindset and success in Making are gateways to children ultimately identifying themselves as technology- and science-capable. As a frame of mind, the mindset is inevitably influenced, if not even dictated by one's self-identity and one's self-concept. Self-concept is the totality of one's perceptions about oneself [15]. According to perspectives such as Control Theory, a person's self-concept serves as the organizing force that drives processes related to self-regulation, such as goal setting and motivation [16]. People use their self-concepts as a guide when making decisions about their lives, such as their field of study and future career [17], essentially fashioning various "possible selves" in imagining the future [18-20].

In social psychology literature, numerous constructs such as self-efficacy, motivation, competence, resilience, and interest can be found to be attendant to the self-concept. Three of the most common and highly significant constructs in determining one's self-concept are self-efficacy, intrinsic motivation and interest or enjoyment. Bandura's social cognitive theory of self-efficacy suggests that the child who thinks: "I CAN (am able to) Make technology things" may progress to thinking "I CAN BE (have a possibility to be) a Maker," and ultimately to "I AM (identify myself as and want to be identified as) a Maker." Hidi and Renninger [21] 'four-phase model of interest' development specifies that situational interest (that a single well-designed Making activity may trigger) is able to develop into a maintained situational interest, then an emerging individual interest, and finally a well-developed individual interest. Among the influencing variables of such interest, Hidi and Renninger [21] have also shown that intrinsic motivation works to affect an individual's intrinsic interest value for an activity. The three-components framework that we adopt in this research as being key determinants of one's self-concept and self-identity is illustrated in Figure 1.

Figure 1. Core determinants of the formation of a Maker mindset

4. The 'Means-to-an-Ends' Approach to Making in Elementary Education

We believe that two critical characteristics of Making in particular contribute to its extraordinary power to support elementary education particularly with respect to the formation of a Maker mindset and identity. This section describes these two characteristics, and discuss how these characteristics require a rethinking of how Making is incorporated into educational settings and curricula. We then describe our proposed approach to Making.

4.1. Two Key Characteristics of Making

I. Making is necessarily integrative of prior knowledge and skills;

This first characteristic relates Making to Papert's [22] constructionism. One important aspect to making things is that it requires a tacit integration of prior knowledge and skills with any new skill or knowledge that is being introduced or acquired for the project at hand. This contextualizes the new knowledge and reinforces prior experience. Making is especially suited to

such ‘cumulative knowledge integration’ because of the breadth of skills it incorporates. For any particular project, topics such as design, dimensional constraints management, electronics, physical prototyping and fabrication, and language may be brought to bear.

II. Making is utilitarian such that Making is seldom an ends-in-itself. One makes things for a purpose of interest.

The second characteristic of Making as a utilitarian activity is informed by Vygotsky’s concept of ‘everyday knowledge’ and ‘scientific knowledge’ [23, 24]. When a student receives a concept in the course of instruction, she is given ‘scientific knowledge’. However, for Vygotsky, that knowledge is truly learned when it becomes something that she uses in daily life. For example, an electrical engineering student may learn about Laplace transforms in an Engineering Mathematics class. She learns the concepts in that class, but she truly understands the transform when she has to use it routinely in the Control Systems class in the next semester. As knowledge is so transformed, it becomes more robustly encoded. Thus, Laplace transforms becomes the ‘means’ to successfully completing the ‘ends’ of Control Systems assignments. This utility concept is echoed in many allied theories and methods of learning and education, for instance, project-based learning [25], ‘learning by doing’ [26], and ‘situated learning’ [27, 28]. As opposed to traditional instructivist classes, Making provides a clearer trajectory of integrating Means and Ends from the student’s point-of-view.

These two characteristics of Making have a number of implications for curriculum innovation involving Making: (i) the Making-based curriculum needs to give room and time for integration activities even if it appears that some of the integrative activity may not be relevant to the exigencies of the current learning goal being introduced; (ii) when students learn in Making projects, any curriculum piece acquired from any class can be brought to bear; (iii) support structures must enable the student to think of herself as a Maker of the artifact, rather than just a learner of the means of production; and (iv) a Making-based class builds upon activities completed in the previous class, in contrast to a hands-on science class about magnetism that has nothing to do with the previous hands-on class on animal habitats.

4.2. Proposed Approach

We propose that an approach that is grounded in and centered on the two key principles described above has the potential to support the formation of a Maker mindset in elementary-school-aged children. We term such an approach the ‘Means-to-an-Ends’ approach to Making. The approach is defined by (i) appropriately-built Making kits that embody the principles and implications above, and (ii) differences in methods of use and implementation of Making into a session with children.

From the curriculum implications above, Making kits embodying the ‘Means-to-an-Ends’ approach need to meet the following requirements:

- a. Make explicit knowledge to be learnt and built upon
- b. Target an integrative activity as ‘Ends’
- c. Be modular and flexible in the Making ‘Means’ tasks required to achieve the ‘Ends’
- d. Be sufficiently open to allow exploration and bringing in of any knowledge piece
- e. Is extensible outside of the constrained setting of initial use

The session implementation requirements of the ‘Means-to-an-Ends’ approach are as follows:

- a. Be centered around the Maker activity
- b. Use STEM- and Making-related language
- c. Be open and exploratory, rather than solely lecture-based
- d. Built on physical materials previously developed and knowledge learnt

To be able to investigate the ‘Means-to-an-Ends’ approach to Making for children, we designed a storytelling-based Making kit, called the ‘Maker Theater’, and implemented it into two workshops with children from our target age group.

5. The Maker Theater

The Maker Theater kit was designed over a two-year period, with three main versions being built to experiment with different connectors, materials, assemblies, setups, etc. Each version was tested for usability with children in the age range of 7 to 11 years old. This section describes the overall and final design of the Maker Theater kit that was used in our two children’s workshops. The Ends that the Maker Theater was developed for is to allow children to tell a ‘lighted story’ through a recorded puppetry show. It requires children to engage in Making as Means to build parts of the kit while creating their story, using arts-and-crafts materials and electronics components.

Figure 2. General schematic of the Maker Theater kit

The kit is essentially a basic battery-switch-resistor-LED circuit. Figure 2 shows the overall schematic layout of our Maker Theater Kit, and Figure 3 shows the completed setup of one actual Maker Theater (left) as well as a top-down view of the Control Board (right). At the heart of the circuitry is the Circuit Card (A in Figure 2) that houses the switch and resistor assembly. The switch is constructed such that simply pushing down on the folded flap will close the circuit and light up an LED, as can be seen in Figure 3. Since our target ages for this kit design ranged as young as 8 years old, and given the amount of time that it would take for a child to assemble the Maker Theater from scratch, some components of the kit were pre-made (e.g., soldering of resistor on paper switches, taping of copper tape) for use by the child. The tasks that

Figure 3. (Left) Completed Maker Theater kit; (Right) Control Board with two paper switches

Figure 4. Screenshots from children's lighted story videos as uploaded on YouTube

a child was explicitly required to do to achieve the Ends of having a full lighted story with the Maker Theater are as follows:

- a. Story brainstorming
- b. Measurement of 'character cards' (G in Figure 2)
- c. Drawing story characters on 'character cards' horizontally or vertically
- d. Drawing the story backdrop
- e. Inserting LEDs into 'character cards' and in the backdrop at desired spots
- f. Setting 'character cards' into bases (F in Figure 2)
- g. Connecting correctly the LED wires from the 'character cards'/backdrop to the Control Board (battery and switch) using the connectors appropriately (male-female pins, paper clips)
- h. Testing each LED circuit
- i. Correctly labeling of switches associated with each story character
- j. Practice the story and identify 'light points' (when in the story a specific LED should light up)
- k. Enact out the story by moving the character cards across the 'stage box', activating the switches, and using voices in front of a video camera

We edit and repackage the recorded stories (see Figure 4 for examples) with a standard 'opening credits' and 'end credits' for the children. The Maker Theater satisfies the kit requirements of the 'Means-to-an-Ends' approach in the following way:

- a. *Make explicit knowledge to be learnt and built upon:* the kit exposes all the internal parts of the circuitry. For example, the resistor is shown explicitly in the Maker Theater, in contrast to most existing Maker kits where the resistor is integrated and implicit (e.g., *littlebits* where the electronic components are wrapped in easy-to-use, but dense modules – Figure 5 left shows

an example of a typical *littlebits* module where the resistor is nowhere to be seen, as opposed to the explicit resistor in our Maker Theater switch design in Figure 5 right).

Figure 5. *littlebits* LED Module (left) and part of Maker Theater switch (right)

- b. *Target an integrative activity as Ends:* Storytelling is an integrative activity that brings together diverse components, ranging from plot to making a character light up.
- c. *Be modular in activities required to achieve the Ends:* Each subassembly of the Maker Theater can be constructed separately, and even repeated as necessary. For instance, the basic LED-switch circuit is designed for a single character, but the same knowledge can be applied to create multiple lighted characters and switches.
- d. *Be sufficiently open to allow exploration and bringing in of any knowledge piece:* The Maker Theater is based on an open design, such that the child is not restricted to only the provided components or to the subject being addressed. Knowledge from science, math, language arts, art and design, or even social studies can be brought into play in the completion of the final story outcome. The child can decide to do any story (the ‘Ends’) that he/she is interested in.
- e. *Is extensible outside of the constrained setting of initial use:* The Maker Theater makes use of simple arts-and-craft and everyday materials (e.g., paper clips) to implement a basic circuit such that it is accessible to children, and they can recreate their stories, or even create new stories at home.

6. Children’s Maker Workshops

6.1. Workshop/Study Description

We conducted two children’s Maker workshops on two successive Saturdays. The workshops were designed to study our approach of Making as a ‘Means-to-an-Ends’ in action, and to provide us with data to elicit thematic indicators of how the potential for Maker mindset/identity formation may show itself in children’s attitudes and behaviors. Recruitment was carried out by disseminating flyers through university email listservs. Parents who expressed interest to register their child for the workshops were emailed a study information sheet and a consent form, that they had to sign and return to the researchers prior to the workshop date. The children worked in teams of two or three for the workshops, which lasted half a day (approximately 4 hours) and took place in a large reconfigurable lab space. Participants of workshop I consisted of 2 pairs of girls, 1 team of 3 girls, and 3 pairs of boys, totaling 6 children teams (13 children), ages ranging from 8 to 9. Participants of workshop II included 3 pairs of boys and 2 mixed-gender pairs, totaling 5 children pairs (10 children), ages ranging from 9 to 10. The workshop design followed the implementation requirements described in Section 4.2, except for requirement (d) as the workshop was a single session and the children had no materials that they themselves constructed prior to the workshop. Table 1 describes the exact procedures of the workshops:

Table 1. Protocol of Workshops

Activity	Details	~ Duration
Arrival and Registration	Each child was assigned a sticker label with an ID.	-
Introduction	<ul style="list-style-type: none"> • Research team was introduced. • Children were randomly paired/grouped. 	10 mins
Story brainstorming	<ul style="list-style-type: none"> • Children brainstormed a story with their partner(s). 	10 mins
Story writing/Pre-interview	<ul style="list-style-type: none"> • Half of the children wrote the brainstormed story. • Half of the children were interviewed individually. 	10 mins
Story writing/Pre-interview	<ul style="list-style-type: none"> • The other half of the children wrote the brainstormed story. • The other half of the children were interviewed individually. 	10 mins
Break	Children are given refreshments.	10 mins
Making activity instruction	A researcher introduces the Maker Theater kit and story-telling activity to the children.	20 mins
Making session	<ul style="list-style-type: none"> • Each pair/group of children uses the Maker Theater kit to create a lighted story, assisted by one helper. • At the end of the session, the children could put up a sticker star with their names written on it on the ‘Mini-Makers Wall-of-Fame’ that we devised. 	1.5 hrs
Story writing/Post-interview	<ul style="list-style-type: none"> • Half of the children wrote the lighted story made. • Half of the children were interviewed individually. 	10 mins
Story writing/Post-interview	<ul style="list-style-type: none"> • The other half of the children wrote the lighted story made. • The other half of the children were interviewed individually. 	10 mins
Break	Children are given refreshments.	30 mins
Story presentation	<ul style="list-style-type: none"> • Children’s lighted story videos are presented to the parents and all the children. • Each child is given a giftbox with certain components of the Maker Theater kit (drawn character cards, paper switches, character bases, battery connectors, and a small booklet describing the steps to building lighted characters). 	30 mins

6.2. Data Collection

Both workshops were audio and video recorded. Figure 6 displays pictures from the workshops, showing the workshop venue, children building their control board, connecting their character cards, and setting up their story stage box. The pre- and the post-interviews were carried out by individual interviewers who followed a semi-structured question format, and assisted the children to complete an online survey on a tablet device. Questions used smileyometers (pictorial 5-point likert scales) [29] as a measure method that is adapted for use with children. The pre-interview queried the children along the three components of self-efficacy, interest, and motivation to engage, as well as their ‘self-concept’, in STEM (science, math) and language arts (storytelling, reading, writing). The post-interview asked about self-efficacy, interest, and motivation to re-engage in making stories using the Maker Theater kit, but did not include explicit

probes about ‘self-concept’ as we did not expect a single workshop session to be able to change children’s views of themselves. About a week after each workshop, an email was sent to the parents of the children who participated requesting self-reports of their children’s behaviors and attitudes in making stories using components of the Maker Theater that was given to the children to bring home. The parents’ reports allowed us to gain an indication of the potential long-term impact of our intervention.

Figure 6. Pictures from children’s Maker workshops

7. Analysis and Results

7.1. Data Analysis

We analyzed the collected data based on the three key determinants of a Maker self-identity/self-concept that we defined as being ‘I can make’ (self-efficacy), ‘I want to make’ (motivation), and ‘I like to make’ (interest)’. We also paid attention to direct indications of ‘I am a Maker’ (self-identity/self-concept). Video/audio recordings of the Making session of eight children groups (4 from workshop I, 4 from workshop II) were analyzed by four coders, who all followed a standard procedure using the same transcription software: (i) Using a fixed list of variables of interest (self-efficacy, motivation, interest, usability, learning, creativity, activity specifics), the video of the Making session was viewed, and episodes that relate to the variables were identified; (ii) The selected episodes were transcribed (speech and behaviors) with timestamps using the Inqscribe software; (iii) Each transcribed event was assigned an initial code (e.g., ‘use of LED’, ‘enactment’, ‘drawing characters’). In total, around 7.5hrs of video was coded in the initial coding process. A single coder reviewed the first-level coding of all the four coders, and

reconciled any inconsistencies. The single coder performed a second-level coding process whereby the initial codes were aggregated into higher-level categories, such as ‘interpretation of LED’, ‘evaluating product’, and ‘independent completion of circuit’. A third-level coding process was carried out whereby the second-level categories were classified as relating to the variables of self-efficacy, motivation, interest or identity. Data from the pre- and post-interview tablet surveys that relate to these variables was also extracted into a spreadsheet and analyzed.

7.2. Results

With permission from the parents, the lighted stories produced by the children in the workshops have been uploaded on YouTube². We present in this section the results obtained from the video coding process, children’s pre- and post-surveys, and parents’ post-reports under the three-part componential theoretical framework of self-efficacy, motivation and interest. Throughout the rest of the text, references to specific participants are made using the children’s ID numbers, e.g., F2-II, M7-III, etc., with the first letter signifying the child’s gender and the numerals indicating whether the child participated in the first or second workshop.

7.2.1. General Engagement and Experience

The children’s experience of the Making session was characterized by three main affective states, detailed in Table 2. Episodes of fun and excitement were the most prevalent, but focused attention translated into a certain degree of tension was also seen at times during electronics tasks. Usability problems also caused episodes of boredom or frustration sometimes when the helper had to repeatedly repair a circuit.

Table 2. Themes in children’s overall experience

Children’s Overall Experience	Extracts from Example Episodes
Fun and excitement	<p>F8-I: Wow we did a lot.</p> <p>F11-I: A lot of what?</p> <p>F8-I: Work!</p> <p>F11-I: Yea, this is hard. Kind of. But it's fun!</p>
Tension	<p>Helper: So that's good. If you want to do the final connection here and hook up those...</p> <p>F2-I: Ya sure.</p> <p>F2-I: (Connects up a wire) This is so tense. Although I already do sewing classes.</p>
Boredom / Frustration	<p>F8-I: This is so boring. There. Does it work now? Is it working?</p>

7.2.2. Determinants of a Maker Mindset

A. Self-Efficacy: I can Make

The notion that ‘I can Make’ was borne out in our video coding analysis through a number of recurrent themes, listed in Table 3. All of the themes cut across the different kinds of tasks that were required in the Maker Theater activity, i.e., idea generation tasks (e.g., character creation), arts-and-crafts tasks (e.g., drawing), practical tasks (e.g., folding switches), and electronics tasks (e.g., connecting wires).

² <https://www.youtube.com/channel/UCOTsSAhzUI1jUfbICtwW2Zg>

Table 3. Themes related to self-efficacy

Maker Theater Self-Efficacy Themes	Extracts from Example Episodes
Showing off (character card drawings, backdrop drawings, working LED, story created)	<i>F11-I:</i> Carmen, Carmen, Carmen, look! Look at the light...it's pretty.
Assessment of own creations (drawings, overall setup)	<i>F9-I:</i> (looks around the room at other groups) I think we made the best of the best.
Evaluation by others	<i>F8-I:</i> (shows character card drawing to F11) <i>F11-I:</i> That'sss pretttyyy. <i>F11-I:</i> Mine is not very good. <i>F2-I:</i> Let me see it let me see it. <i>F2-I:</i> I like it.
Successful completion of tasks	<i>M2-II:</i> We are done. I did it, I did it, I did it. Yeah. <i>M9-II:</i> We are awesome, We are awesome, We are awesome.
Independent completion of tasks	<i>M1-I:</i> I made this one (LED connection) work.
Volunteering to help / Teaching others	<i>F8-I:</i> Excuse me how do I put my girl in it? (asking helper for help to put her character in base) <i>F2:</i> I'll show you, I'll show you. Let me show you.
Successful circuit debugging	<i>F11-I:</i> Hey mine is not going on (pressing her switch). <i>Helper:</i> There must be a... <i>F11-I:</i> Oh what tape is that? <i>Helper:</i> Oh yea.. it must not be.. connected somewhere. <i>F11-I:</i> Oh this wire! <i>Helper:</i> There you go yea. Let's hook that back up. <i>F11-I:</i> (She connects up the wires) <i>F11-I:</i> (Tests the switch) Yaaayyy!
Knowledge of process	<i>M13-II:</i> Now we are going to put this onto here (pointing to wires from box to base). <i>M11-II:</i> (watching other group behind him) <i>M13-II:</i> And I'm gonna hook these on to that.

B. Motivation: I want to Make

Various kinds of behaviors provided evidence that the children wanted to engage in the Making session. We list in Table 4 the themes that emerged from our analysis related to the children's motivation with respect to various Maker Theater tasks.

Table 4. Themes related to motivation to engage

Maker Theater Motivation Themes	Extracts from Example Episodes
Wanting to be here	<i>F2-I:</i> At first I was really shy, and I and I felt like I didn't want to be here, but now I do. <i>F8-I:</i> Yea I was also really shy before.

Wanting to bring parts home	<i>F11-I:</i> Are we gonna be able to bring anything home?
	<i>F2-I:</i> Do we get to bring our character?
	<i>Helper:</i> Yup. You'll be able to bring your character
	<i>F8-I:</i> But, are those lights going to be able to be?
	<i>Helper:</i> Oh yea. I think the only part that is not going to be sent home is the battery, which you can...
	<i>F8-I:</i> ohh...(a disappointed kind of oh)
Wanting to share	<i>Helper:</i> Well you probably have some 9V battery at home you can use.
	<i>F8-I:</i> So we can't...I want some of those batteries
Wanting extra effects, e.g., to make bloopers, making-of video, background music	<i>Helper:</i> Ok, you guys ready to start hooking some of this stuff up?
	<i>M13-II:</i> They're gonna put this on YouTube!
	<i>M2-II:</i> You know what I am gonna do? I am gonna make a Stop motion video of us creating the movie.
	<i>F11-I:</i> Can we have bloopers?
Unsolicited thought	<i>Helper:</i> I don't know if we're gonna have time for that. Cause we're going to be like filming these for everybody.
	<i>Helper:</i> Start thinking about what you want your planes to look like, I am gonna grab you a pencil.
	<i>M2-II:</i> I already know exactly what mine's gonna look like.
Requesting circuit components	<i>F1-I:</i> If we have an extra light at the end, we can like shine up somebody's dress
	<i>F2-I:</i> Oh wait, actually I do want a light. I want a light like right here for my dog.
	<i>F8-I:</i> Can I put a red light right here? (shows helper her character card)
	<i>Helper:</i> Like at the end? Yea sure.

C. Interest: I like to Make

Evidence of interest episodes generally occurred after a task was accomplished, e.g., completing a character card drawing, taping the batteries, but they were seen overwhelmingly when the children had the LED lit up on their character or background. Table 5 shows the themes indicative of the children's interest in terms of their comments during these specific episodes.

Table 5. Themes related to interest

Maker Theater Interest Themes	Extracts from Example Episodes
Joy and enthusiasm (seen behaviorally with expressions of smiles, thumbs-ups, hi-fives and gasps, and through speech with comments like 'Yay', 'it's pretty', 'it's cool', 'Woah')	<i>F2-II:</i> Is it working now or? Let me try. <i>F2-II:</i> Yaaayyy it's glowing! I think we're just gonna have to keep this light on the entire time
Play (repetitive interaction with the circuit and acting with the lighted character)	<i>Helper:</i> Okay, moment of truth, if you want to push this switch down to see if it lights up <i>M13-III:</i> (pushes switch down, it lights up, student smiles and repeatedly pushes switches and watches LED light up) <i>Helper:</i> (works with M11 to connect LED) <i>M13-III:</i> (continues to push down circuit and smiles and sticks his tongue out)
Sharing (eagerness to show their products to peers and helpers)	<i>F11-II:</i> Carmennnn look at my beautiful light (takes her character stand by the rod and presses switch to light up her blue LED)

7.2.3. Post-Workshop Indicators of Identity/Mindset Formation

We described in Table 1 how our workshop protocol included the children writing their name on a ‘sticker star’ and pasting the star up at the end of the Making session on a wall that we visually decorated as the “Mini-Makers Wall-of-Fame” (Figure 7). A key example of the potential of our Maker Theater activity to support the formation of a Maker identity in the children is the unexpected enthusiasm that was seen in the children to post their named ‘star sticker’ on our ‘Mini-Makers Wall-of-Fame’. The extracts below provide evidence of the extent of this enthusiasm:

Figure 7. Mini-Makers Wall-of-Fame

F11-II: (To helper) So you're gonna hang this up, for other people to see? (referring to the Mini-Makers Wall-of-Fame)

Helper: Yea you're gonna be on this wall (points to Wall-of-Fame)

Helper: You're the first. We're the first.

F11-II: We're the first! We need to hang it up there! (pointing to Wall)

F8-II: Can I put this up there? (holding star out to the Wall-of-Fame)

Helper: Not yet.

F8-II: Awww...

The parents' post-reports of their children's interactions in the days following the workshop enabled us to explore the longer-term indicators of behaviors and attitudes of the 'Means-to-an-Ends' approach as embodied in the use of the Maker Theater kit. Seven parents' reports were obtained. In Table 6, we present the themes that arose out of our qualitative coding (open, focused and axial/thematic) of the parents' reports.

Table 6. Post-workshop indicators of children's Maker identity/mindset formation from parents' reports

<i>Self-Efficacy (I can)</i>	<i>Motivation (I want to)</i>	<i>Interest (I like)</i>
<ul style="list-style-type: none"> • Making components re-use/exploration • Conceptualization of new 'Ends' (story) 	<ul style="list-style-type: none"> • Wanting Making "weekly outing" • Expressed disappointment at no follow-up sessions • Verbal plans for re-use 	<ul style="list-style-type: none"> • Showcase of products and story video • Keeping parts in "special place"

8. Discussion

Within the scope of our definition of Making for children in this article, we argued that instead of solely emphasizing STEM learning through Making for children, it is of greater impact to engage in research that looks at how Making can support the formation of a Maker mindset in children. The instilling of a self-identity as being a Maker in a child is at least as important at the critical development period of age 8 to 11 as the transmission of knowledge and skills. The latter will arguably be picked up by the child in the course of the child's cognitive and motor development, if a Maker mindset is present throughout. The Maker Mindset supports the formation of the children's identity as being individuals who are able to make technological things for themselves. Our longer-term hypothesis is that such a perspective on Making would also lead to

more robust learning for children as they willingly seek to acquire necessary (STEM) knowledge to make the technological (or technologically-supported) things of their interest. Overall then, this mindset may serve as an effective gateway to children possibly identifying themselves as being STEM-capable and STEM-interested individuals who would pursue STEM careers.

Our contributions in relation to the support of Maker mindset formation thus are three-fold: first, we proposed a ‘Means-to-an-Ends’ approach to the design of Making activities for children in our target age range, Second, we showed how the ‘Means-to-an-Ends’ approach can be operationalized in a concrete Maker kit design (the Maker Theater) and workshop implementation. And third, we defined a three-componential framework of self-identity that we used to uncover behavioral and attitudinal themes of indications of Maker mindset formation during Making sessions with children.

The ‘Means-to-an-Ends’ approach essentially proposes that Making should be seen as a Means needed to achieve an Ends of interest to the child. It is a theoretically-grounded framework that suggest various requirements for Making activities to address mindset formation, instead of focusing solely on learning objectives (as a ‘Making lesson’ aimed at teaching children, for e.g., how to build a circuit, would). This is especially important as the setting for Making is slowly moving beyond children’s workshops to inclusion in the school curriculum. The themes uncovered in our studies (e.g., Showing off, Self-assessment, etc. for *self-efficacy*; Wanting to be here, Wanting parts for home, etc. for *motivation*; Enthusiasm, Play, etc. for *interest*) may be used as a guide for evaluation in qualitative studies of mindset of children engaging in Making.

The work that we present in this article is limited by the fact that we studied children in a one-shot workshop. However, our purpose here was not necessarily to test the effectiveness of the Means-to-an-Ends approach through the Maker Theater, but to explore how such an approach may influence behaviors and attitudes that would influence mindset in a Making session. We saw how a range of experience states (fun and excitement, tension, boredom and frustration), and themes of how ‘I can’, ‘I want to’, and ‘I like’ are manifested in the Making sessions. These findings are valuable to understand how the Maker mindset is formed over time, from session to session. Our plans for future work include investigating how a series of sequential Maker workshops would influence children’s attitudes and behaviors towards Making and STEM, and whether the thematic indicators that we presented in this article may be first, formalized as a checklist, and second, generalized to sustained (long-term) Maker mindset behaviors and attitudes.

9. Conclusion

We have presented an account of our research in Making for children from its theoretical and philosophical premises to its implementation into children’s workshops. Although the body of work on Making and digital fabrication for children is rapidly growing, few new visions have been presented apart from its value in providing a constructivist and constructionist path to learning. Our goal with this article is to provide an alternate direction in which Making can make an impact on children in education. Much research is still needed for this direction to become a fully functional and sustainable part of elementary education, but we hope to have provided at least a starting point for further research.

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