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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.

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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

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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 10–14 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 14–18 using MIT's Pico Cricket kit.[1] 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, Alexanderet 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/.

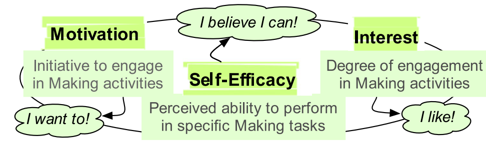

Fig. 1. Core determinants of the formation of a Maker mindset.

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 Fig. 1.

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