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Making in the Classroom:
Longitudinal Evidence of Increases in Self-Efficacy and STEM Possible Selves over Time

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1. Abstract

Making refers to the hands-on practice of creating technology-based artifacts that typically involves things like electronics, programming, and 3D printing. Practices in Making have been spearheaded by the rise of the Maker movement, resulting in the spread of Makerspaces for both young people and adults worldwide. However, Making is also being increasingly incorporated into school settings. This is despite the fact that little research has evaluated the potential consequences of Making in schools. We present a two-year longitudinal study investigating the effects of integrating Making into existing school curricula at a public elementary school that primarily serves students from underrepresented groups in STEM (Science, Technology, Engineering, Mathematics). We focused on whether engaging in Making led to changes in self-efficacy, interest, and identification with both Making and science. We further examined more distal potential changes in STEM career interest and STEM possible selves. Results showed that students exposed to a Making-based science curriculum evidenced significant increases in four of the eight dependent variables tested (Making self-efficacy, science self-efficacy, science identity, and STEM possible selves). These findings demonstrate the utility of curriculum-aligned Making, particularly in terms of fostering self-efficacy, science identity, and possible selves among students from underrepresented groups.

Keywords. Making; Digital fabrication; Teaching/learning strategies; Elementary education; Science education.

2. Introduction

As the Maker movement becomes mainstream, Making and digital fabrication practices are slowly entering schools as a desirable approach. The question of the actual benefits this brings to individual learners is of utmost importance. A pedagogical approach based on Making has a high cost-benefit ratio due to the non-trivial infrastructure and materials required for implementation at a school, or even in a single classroom. Understanding how integrating Making into a school curriculum affects learner variables will not only help to inform educational policy but also validate the *raison-d'être* of further research in this area. This paper presents a two-year longitudinal study of the impact of children's engagement in curriculum-aligned Making activities within the formal school context. The study was conducted with 190 students in a low socioeconomic status public elementary school that predominantly serves students from underrepresented populations. While the effects of engaging in Making could apply to a host of potential variables (e.g., learning, comprehension, vocabulary, test performance), the current research focuses on the impact of engaging in Making on the self-concept (i.e., beliefs about who one is). Specifically, we addressed effects on students' self-efficacy, interest in, and identification with both Making and science. We also examined more global effects on career interest in STEM (Science, Technology, Engineering, Mathematics) and STEM-related possible selves. All of these variables broadly capture beliefs about who one is (i.e. self-concept) and have been shown to have consequences for behavior (e.g., Leary & Tagney, 2003).

We believe that Making, as a set of easily accessible technologies (related to electronics, programming, digital fabrication) enabling construction of artifacts, can affect self-concept variables in both technology and science because, within the formal context of the classroom, it is able to address students' basic psychological needs (particularly autonomy and competence) in a distinct manner. In typical science classes, students are usually *given* the tools and materials to conduct their science experiments. This certainly does not have the potential to affect students' self-concept as Makers, but is also limited in its ability to affect their self-concept as scientists. In Making-based classes, students *build* the tools for their science experiments using technology. Because a key characteristic of Making is that it has a "low threshold" (Chan, Pondicherry, & Blikstein, 2013), students are able to both construct their tools and conduct their science experiments using their constructed tools in the formal classroom. This should affect both students' Maker and science self-concepts, as it leads them to feel that they are more autonomous and competent not only in terms of creating using technology, but also in terms of doing science.

In the following sections, we review the role of Making in education, as well as studies that explicate the effects of Making particularly as they relate to the self-concept. We then describe our approach to curriculum-aligned Making and the various psychological constructs that we hypothesize it would affect. We follow up with our study methods and results.

3. Background and Theoretical Foundation

3.1 Making

Making broadly refers to the practices surrounding the use of a set of technologies that include, for instance, electronics, 3D printing, programming and microprocessors, as despecialized means of prototyping and creating technology-based artifacts. It is typically associated with values and characteristics such as play, innovation, intrinsic motivation (Dougherty, 2013) and technological literacy. Research on Makerspaces is still in its infancy, with most assessments in practice being done through self-assessments, rubrics and portfolios (Peppler, Keune, Xia, & Chang, 2017). Furthermore, according to a survey of the literature on

Making in education (Papavlasopoulou, Giannakos, & Jaccheri, 2016), the majority of empirical findings are qualitative in nature and based on samples of fewer than 50 participants. As briefly mentioned by Giannakos, Divitini, and Iversen (2017) and from our own review and analysis of the literature, there is currently a lack of work looking at the *effects* of engaging in Making within an educational setting. Evidence of the impact of Making integrated into the school curriculum at a broader level is even more scarce.

3.2 Making in Education

Makerspaces are increasingly found in schools, libraries, museums, community centers, paid summer camps, and after school programs. For instance, the FabLab@School worldwide network of after school or club-based programs supports children in solving personal and community problems by making the tools they need (Blikstein & Krannich, 2013). More recently, the national 'Makerspace in School' program has been established in Sweden, where 15 elementary schools have integrated digital fabrication into their educational practices to various extents (Eriksson, Heath, Ljungstrand, & Parnes, 2017).

The integration of Making in education is mainly founded on Papert's idea of constructionism (Blikstein, 2013) – hands-on learning through the creation of digital and physical artifacts. With constructionism, Making brings in other aspects to learning such as being project-based (working to produce an artifact or product as a project), discovery-based (learning new skills and knowledge sets as needed during the process), integrative across subject matters (using knowledge from any discipline necessary to complete the artifact) and collaborative (teamwork, sharing knowledge, and helping others). These philosophies contrast sharply with the conventional instructivist approach that is prevalent in current schools, which tends to be optimized for student achievement on standardized tests.

The implementation of Making in the classroom, therefore, has distinctive features compared to informal or out-of-school Makerspaces. Making in formal educational contexts typically has the additional constraint of satisfying learning objectives, while ensuring that the creative, project- and discovery-based spirit embodied in the Maker movement is maintained. Fulfilling both goals simultaneously is very challenging because Making and formal education tend to have conflicting methods and standards. For example, while Making emphasizes and values discovery and innovation, modern public school systems are driven by scheduled lesson plans and accountability (Halverson & Sheridan, 2014). Conversely, rigid learning objectives are not typically a major focus in informal Makerspaces.

The tension between Makerspaces and conventional school environments implies that the activity of Making in formal school contexts is not always of the same type as Making done in informal spaces. Some researchers have made the distinction between Making as “step-by-step, recipe-like, construction activities” and Making as inquiry-based tinkering. In conceptualizing Making for the public school classroom, however, we argue that even Making implemented as guided, stepwise activities has value. Indeed, guided activities may actually be the only viable path for in-school implementations of Making, given the present constraints of formal public schooling environments. In most schools today, there are a variety of constraints to implementing more free-form Making activities, such as the emphasis on testing, discipline, and regimented schedules as well as large classrooms. A guided approach to Making may initially serve to introduce students to skills and knowledge that are foundational for Making (e.g., what circuits are, how to connect circuits, what batteries do). In our own project, we have seen that after this initial phase, students are eventually able to move beyond skills and knowledge to actually engage in mental models and practices needed to address the more open-ended nature of exercises inherent in inquiry-based tinkering (Chu et al., 2017a, 2017b).

3.3 Making and Self-Concept formation

Self- and identity-related processes are fundamental in human psychology, with self-perceptions, self-evaluations, self-feelings, and self-concepts playing prominent roles in many psychological theories (Leary & Tagney, 2003). Because self-related processes have a pervasive influence, both within and beyond the educational context, it is important to consider how educational practices (such as our integration of Making into the science curriculum) bear on these processes. In this investigation, we drew specifically on Self-Determination Theory and theories about self-efficacy and possible selves, given prior evidence of these theories' applicability to our target domain of children's developing academic and vocational interests. Taken together, these theories implicate self-related processes in the educational domain, and suggest clear mechanisms by which Making experiences might contribute to these processes.

Self-Determination Theory. With respect to students' motivation and engagement with science, Self-Determination Theory (SDT; Ryan & Deci, 2000; 2002) is a broad perspective on human motivation that emphasizes the importance of intrinsic motivation for adaptive functioning and well-being. According to SDT, when people's basic psychological needs for *relatedness*, *competence*, and *autonomy* are satisfied, they will be more intrinsically motivated (i.e., engage in activities based on personal enjoyment or interest). Intrinsic motivation has been linked to a variety of positive outcomes, including, academic performance (e.g. Deci, Vallerand, Pelletier & Ryan, 1991; Fortier, Vallerand & Guay, 1995; Niemiec & Ryan, 2009; Taylor, et al., 2014). Specifically, with regard to learning, SDT contends that satisfaction of basic needs and intrinsic motivation fuel self-concept development (Deci et al., 1991; La Guardia, 2009; Ryan &

Deci, 2000). Intrinsically-motivated learning experiences prompt people to assimilate what they learn into their sense of self, eventually making it an integral component of their self-concept. This represents a promising mechanism by which classroom Making experiences (which support students' needs for autonomy and competence in particular) can foster identification with science.

***Self-Efficacy*.** The psychological construct of self-efficacy refers to a person's subjective evaluation of their ability to perform well in a particular domain (Bandura, Adams, & Beyer, 1977; Bandura, 1977; 1982). In the academic domain specifically, there is abundant evidence that greater self-efficacy is associated with various outcomes including engagement and performance in school (Bandura & Schunk, 1981), career aspiration (Bandura et al., 2001), and choice of college major (Wang, 2013). Given that Making activities involve students very directly in creating technology, and then in using the tools they have made to execute projects, it is plausible that these kinds of activities will be more effective at fostering students' science self-efficacy than conventional approaches to science instruction. Building self-efficacy in this domain should increase the likelihood that students will continue to engage with science into the future (e.g., by electing to take more science or technology-related courses in high school, or by selecting STEM-related college majors).

Possible Selves. A final psychological construct that provides a useful framework for conceptualizing children's self-concept development in science domains is the idea of possible selves. Possible selves refer to future-oriented aspects of the self-concept that reflect identities that a person believes they could one day possess (Markus & Nurius, 1986). Possible selves have been broadly implicated in goal-setting and motivation, with evidence for their role in the academic domain being most relevant to this investigation. In the academic domain, having positive, *desired* possible selves (as opposed to negative, *feared* possible selves) is associated with increased engagement with school and higher school attendance (Oyserman, Terry, & Bybee, 2002), particularly when coupled with concrete strategies by which these possible selves can be realized (Oyserman, Bybee, Terry, & Hart-Johnson, 2004; Oyserman, Bybee, & Terry, 2006). If students do not see a science-related future as a possibility, they will not be engaged or motivated in their science classes in the present (see Hannover & Kessels, 2004). Again, the very direct nature of students' involvement in Making activities suggests that Making may be an especially effective means of encouraging the development of science-related possible selves, because they see firsthand that they can do science-related activities now, and thus possibly later.

Making and Self-Concepts: Prior Evidence. The bulk of literature on Making effects has focused on studying how children's engagement in Making may foster Maker values in them, such as creativity (e.g., Giannakos, Divitini, Iversen, and Koulouris (2015)), design thinking (e.g., Smith, Iversen, and Hjorth (2015)), and technological fluency (e.g., Weibert, Marshall, Aal, Schubert, and Rode (2014)). The acquisition of these values has been collectively referred to as having a Maker mindset (Dougherty, 2013), which may eventually translate to self-concept formation (Chu, Quek, Bhangaonkar, Ging, & Sridharamurthy, 2015). The investigation of self-concept formation, however, requires longitudinal studies that are still scarce. Two such studies, for example, have been conducted by Dixon and Martin (2017) and Flores (2018).

Through narrative inquiry from interviews at public events with 11 youth who have been engaged in Making projects for a period of time, Dixon and Martin (2017) defined three trajectories of participation in Making: Exploration, Exchange, and Deliberate Engagement. They argue that these three frames define different ways of *knowing*, *being*, and *doing.* Youth with an exploration frame tend to be motivated through the sense of accomplishment that they receive upon completion of an artifact; they see Making as a generalized practice, and identify as a primary Maker. Youth with an exchange frame are motivated by the sharing of their artifact with others; they tend to become increasingly specialized in Making, and are “agentive but supported” Makers. And youth with a deliberate engagement frame have broader motivations such as to inspire others to make, engage in domain-specific Making, and gravitate towards professional (career-related) identities as Makers.

Flores (2018) studied an approach to science instruction called ‘problem-based science’ that integrated Making in fifth- and sixth-grade classes at a middle school Makerspace. Over eight academic semesters of study, the author stated that “only small shifts in attitude were revealed by the paper surveys” (p. 26). Qualitative data sources (interviews and observations), however, “revealed evidence of increased self-efficacy around finding, addressing and designing solutions to real problems” (p. 26). Flores summarized the types of benefits that students gained in terms of habits and mindsets as being about ‘agency’ (asking questions, risk-taking, problem-solving), ‘constructive autonomy’ (self-direction in work), ‘community’ (sharing, mentoring, giving credit), and ‘creativity and cognition’ (critical analysis, hands-on learning, divergent thinking).

Since Making in formal educational contexts requires a focus on learning goals, a relevant question is whether Making activities can not only foster Maker identities but also subject matter-related identities. School Making is typically aligned with different subject matter, most often with Computer Science, Engineering, and Mathematics (Peppler et al., 2017). Others and our research team (e.g., Bevan (2017)) have also actively looked at aligning Making particularly with elementary school science. From a survey of the available literature, which is again mostly qualitative in nature, a 2014 report on Making and tinkering as educative practice by the National Research Council (Vossoughi & Bevan, 2014) highlighted that there is evidence that Making programs can support “new intellectual dispositions, identities and future trajectories” (p. 14) with respect to STEM. The report drew from studies such as Fields and King (2014) and Bowler (2014), which we note, were not necessarily done with children or in school settings. However, the authors did recognize that evidence from these studies are mostly “observed or self-reported during or soon after making experiences” (p. 14), and there is little evidence yet on the “influence of making/tinkering experiences on young people’s long-term trajectories” (p. 14). The current report aims to fill that gap by examining the effects of a curriculum-aligned Making intervention on Maker and science identities over the span of two years.

4. Curriculum-Aligned Making in the Classroom

4.1 Description of our approach and theoretical rationale

Over the course of a two-year long integration of Making in the elementary school classroom, we developed 36 Making kits and activities that were targeted at grades 3, 4 and 5. The Making activities were aligned with state-mandated learning outcomes (reference omitted for blind review) for various topics in elementary school science. The kits and activities were developed by a design team with expertise in electrical engineering, computer science, child-computer interaction and design, and education and classroom pedagogy, informed by feedback from participating teachers. The Making activities made use of basic arts-and-crafts, and one or more of the three core technologies in the Maker movement: basic electronics, 3D design and printing, and basic programming through a block-based interface.

There are two main distinctions of our Making activities as compared to common hands-on science experiments. First, in usual science experiments, students typically use materials given to perform an experiment. In contrast, in Making activities, students build tools or instruments to help them perform an activity or experiment and support their learning. For example, in a lesson on mixtures and solutions, students may be asked to first pour sugar into a glass of water and observe how the sugar seems to disappear in the water, and then pour sand in a different glass of water, and observe that the sand remains at the bottom of the glass. In a Making activity on the same topic, students would build their own electronic mixer to facilitate mixing and observation of the effects of different types of substances in water. Second, in typical hands-on learning, the process of doing science activities (e.g., using an inclined plane or block-and-tackle for a class on mechanical advantage) may not facilitate the completion of subsequent activities (e.g., modeling a volcano with vinegar and baking soda). Curriculum-aligned Making in the classroom, conversely, is cumulative and skills learned can transfer from one activity to the next (e.g., learning how to build a circuit can help students build a pushing mechanism in one class and an electronic dipper for baking soda in another).

Following our interest to impact students' science and Making self-concepts, the design of this curriculum was framed by the three basic social psychological theories introduced above (self-determination theory, self-efficacy theory, and possible selves theory). These perspectives converge to suggest that fostering positive experiences of autonomous Making should be an effective means to promote students' Making and science interest and identification.

Self-Determination Theory (Ryan & Deci, 2000) suggests that classroom Making can foster science identification by meeting students' basic psychological needs, and thereby increasing their intrinsic motivation. There are particularly clear connections between Making and two of the three basic psychological needs that SDT specifies, namely, *autonomy* and *competence*. In the current Making intervention, students completed projects in an autonomous fashion, as they were responsible for assembling the necessary tools and materials and then completing the projects themselves. The autonomy Making affords students is unique, particularly when contrasted to traditional top-down approaches to instruction. At the same time, students' competence is supported by being provided with assistance only when needed (in the form of additional instruction, so that students' autonomy in completing the activities was preserved) to ensure that the projects were completed successfully. Though somewhat less direct than the influences on autonomy and competence, our Making intervention was designed in a way that may also support relatedness needs as well. Most of the projects were completed in groups and often required teamwork. Further, instructors were kind, supportive, and non-evaluative towards students. This should create both a sense of peer to peer connection and a sense of peer to instructor connection. By helping students satisfy these basic psychological needs in the context of science-related projects, SDT would predict that this intervention should foster intrinsic motivation in the science domain (as indicated by students' reports of interest in science-related classes and careers) as well as the development of science-related identities.

We also expected our Making intervention to improve students' self-efficacy in science (i.e., positive evaluations of their own ability to be successful in this domain; Bandura, 1977), which in turn should contribute to a more enduring interest in science. By supporting students' autonomous completion of science projects involving the use of various technologies, the Making intervention allows students to experience success in this domain firsthand—in a way that traditional approaches to science instruction do not. These experiences should contribute quite directly to students' self-efficacy in science. This should in turn increase the likelihood that students develop long-lasting interests in science (e.g., Bandura et al., 2001; Wang, 2013).

Finally, with respect to possible selves, evidence suggests that an important part of establishing possible selves is to provide exposure to previously unexplored options (Beier, Miller, & Wang, 2012; Dunkel, 2000; Dunkel & Anthis, 2001; Ibarra, 2005; Markus & Nurius, 1986; Marshall, Young, Domene & Zaidman-Zait, 2008). By highlighting the practical value of science knowledge to solve problems and introducing the concepts of science through applied engineering concepts, the Making intervention should work to establish STEM-related possible selves. The establishment of STEM-related possible selves should in turn facilitate students' long-term commitment and persistence in STEM (Cross & Markus, 1994; Hoyle & Sherill, 2006; Mills, 2014; Oyserman, et al., 2006; Plimer & Schmidt, 2007; Strauss, Griffin & Parker, 2012). Possible selves were particularly relevant in the school where this particular study was performed, given that most of the students were from underrepresented groups who were unlikely to have salient role models from the science domain.

4.2 Illustrative examples of classroom Making-based activities

We describe briefly below two examples of the Making activities that the students engaged in over the two year study. Each Making activity was aligned with a different set of science learning standards in the school curriculum and followed the approach outlined in the previous section. A sample of a full Maker lesson plan is given in the Appendix A. Additional example Making lesson plans and activities are available at (url omitted for blind review).

Example 1:

Figure 1 shows the Maker activity for the fourth-grade science curriculum unit on air pressure and weather conditions. Figure 1A shows a simulation model that students build using basic electronics, and arts and craft methods with paper switches, conductive tape, and paper circuit boards. The model shows that high pressure is related to sunny weather and cloudy conditions occur in low pressure areas. After having assembled the model, the students 'run the model' mentally, pressing the appropriate switch depending on whether the pressure is High or Low in the areas near their home.

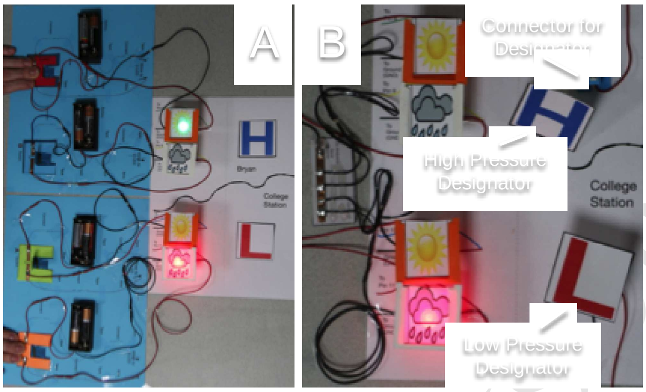


Figure 1. Maker activity for 'Weather' science unit

Example 2:

The fourth-grade classes engaged in a Making activity aligned with the science unit of 'Organisms and Environments'. The learning goals for that unit were to understand that organisms adapt to their environment in order to survive. Examples of adaptations include the shape of a bird's beak or the leaves of a plant. The students were given the task of designing a bird beak that would pierce through a foam board, much like a bird might do to gather food. Working in pairs, the students designed a bird's beak using the web-based 3-D design software Tinkercad (*www.tinkercad.com*). After learning the basics of the Tinkercad program, students spent one day designing a bird's beak that could accomplish the given task. Students had to verbalize to their partner and to other groups why they believed their design would be successful. The classroom team then printed their designs using 3-D printers in the classroom and in our research lab. The students attached their 3-D printed bird's beak to a 3-D printed crankshaft machine, and powered their device using a basic electronic circuit with a geared rotating motor as the load and a switch made out of card stock and conductive copper tape. As a final activity for this unit, the students attempted to pierce the foam board with their motor-powered 3-D printed-beak. Debriefing time was spent discussing why some beaks were successful and some were not. Figure 2 shows some of the beaks designed by the students.

Figure 2. Beaks designed by students in 'Organisms and Environments' Unit

These two examples illustrate how the Maker activities in our intervention are founded on key points of our approach described before: i) The activities satisfy clear learning standards associated with a specific topic in the science curriculum; ii) The activities make use of at least one core Making technology: electronics in the 'Weather' activity, and both electronics and 3-D printing in the 'Organisms' activity; iii) Students build the tools that they would then use to perform science experiments: in the 'Weather' activity, students built components for a quiz-like system to express their knowledge of weather pressure. In the 'Organisms' activity, students made birds' beaks that not only allowed them to express their understanding of adaptation but also to test it; iv) Students' learning of technology skills is cumulative and build up from lesson to lesson: in the 'Organisms' activity, students use the knowledge about connecting motors that they learned in the 'Weather' activity previously to power their birds' beaks; and v) The activities consist of subtasks that students can perform autonomously, thus providing them with the possibility of creative personalization (e.g., in Figure 2, notice that some students engraved their initials in their bird's beak).

5. Study Description

5.1 Participants

The study was conducted in a local elementary school in third-, fourth-, and fifth-grade classrooms (students aged 8 to 11 years old). The school administration selected six classes (two from each of the three grades) for participation in the study. The majority of the students in the school were from underrepresented groups in STEM (72% Latino, 26% African American, 96% on reduced lunch programs, >50% Low-English Proficiency). The current study was conducted over two academic school years (2015-2016 and 2016-2017) and includes all students who had data for at least 3 waves of data collection. We determined this as a minimum threshold of involvement in the project for plausible changes in our variables of interest. This was important because, like many lower socio-economic status schools, our focal school had a high rate of instability in student population. Some students were only in the program for a single week. Based on these criteria, the current analyses included a total of 190 students (91 females, 99 males, 131 Hispanic, 51 African American, 7 Caucasian, 1 other/unknown). Of these students, some ($n = 64$) were in the program both years and some were in the program for one year ($n_{2015} = 62$; $n_{2016} = 64$). Some initial results from the first year of data collection have been published in an earlier paper (Anonymous, 2017).

5.2 The Intervention

The Making activities were deployed during the formal science class for one week at a time (that we henceforth refer to as a 'Maker Week'). The elementary school academic calendar in the school district is such that each six-week period addresses one science topic. For a 36-week academic year, this totals up to six six-week periods, or six science topics being addressed. We deployed one Maker week for each science topic. Making activities were designed in consultation with the teachers, and each science lesson of the Maker week consisted of five main parts: i) initial instruction by the teacher; ii) Making instruction by a member of the design/research team; iii) students' engagement in Making; iv) conducting a science exercise with the artifacts made; and v) post-exercise notetaking and discussion led by either the teacher or the researcher. Other than the guided instruction portions of the class, students were encouraged to work relatively autonomously and in free-flow interactions.

5.3 Data Collection

All classroom sessions were videotaped for future qualitative analysis. However, the current manuscript focuses on the quantitative self-report portion of the study. Students were asked to complete surveys at the beginning and end of each school year as well as at the end of every Maker week. We adapted 'The Self Perception Profile for Children' (SPPC; Harter, 1985) as the general format of the surveys. The SPPC is a self-report questionnaire originally designed to measure children's self-esteem and has been widely validated (e.g. Muris, Meesters & Fijen, 2003). In a "structured alternative format", each child was presented with an affirmative statement about themselves and its negative counterpart (e.g. "I like doing math" OR "I don't like doing math"). Students were instructed to make an initial choice between the two statements, then rate how true the statement they chose is of them ("sort of true" OR "really true"). Students completed a practice item as a group to make sure they understood the format, and then completed the rest of the survey. All responses were recoded into a 1 to 4 Likert-type scale (1 = endorsed "I don't like math," then "really true," 4 = endorsed "I like math," then "really true").

When computing composites, all items were coded such that higher numbers would indicate greater interest, efficacy, and identification.

This manuscript reports the results from these surveys for eight variables we hypothesized that the intervention would influence: 1) Maker self-efficacy (i.e., the belief that one is good at Making), 2) science self-efficacy (i.e. believing that one is good at science), 3) Making interest (i.e., liking Making), 4) science interest (i.e. liking science), 5) STEM career interest (i.e. a measure of how much students would be interested in specific STEM careers such as scientist and engineer), 6) Maker identity (i.e., identifying Making as important to one's self-concept), 7) Science identity (i.e., identifying science as important to one's self-concept), and (8) STEM possible selves (i.e., the belief that one may have a job someday in STEM, such as a job where they "discover new things" or "help build new things"). The first five of these were assessed at every data collection point (i.e. pre-study, end of every intervention/Maker week, and post-study) and the latter three were assessed only at pre- and post-study. The final items used to measure each variable are listed in Appendix B. To ensure the validity of the measures, we developed face-valid items–most of them derived from prior research (as specified below).

Making and science self-efficacy. We assessed students' self-efficacy in both Making (M = 3.27, SD = .88) and science (M = 3.36, SD = .87) using two face-valid items (one for self-efficacy in each domain) adapted from Bandura (2006). For Maker self-efficacy, participants picked between two statements: "I am good at building or making things" vs. "I'm not very good at building or making things." For science self-efficacy, students picked between the statements: "I feel I am very good at science" vs. "I worry whether I can do the assigned science work." For test-retest reliability, we examined the correlations between the first and second measurement points for each measure. We did this because we expected some degree of change in variables over time (e.g. students who initially score lowest might have more to gain from Making than those who score highest). The correlation coefficient *r* between the first two measurement points was .33 for science self-efficacy and .42 for Maker self-efficacy. Given both measures were based on one single item, these moderate correlations suggested some rank order stability. We also assessed self-efficacy in other subjects less relevant to the intervention (e.g., language arts). Results for these other domains are not reported in the current manuscript but can be obtained from the first author by request.

Making and science interest. We developed two face-valid items to measure students' interest in Making ("I like to build or make things" vs. "I don't really like to build or make things", *M* = 3.32, *SD* = .78) and science ("I like science" vs. "I do not like Science", *M* = 3.56, *SD* = .77). The correlation coefficient between the first two measurement points for was .52 for Making interest and .47 for science interest, suggesting fair rank order stability.

STEM career interest. Interest in STEM careers was assessed by asking students to indicate whether they would want to have various STEM careers in the future (e.g., "I want to become a scientist when I grow up" VS. "I do not want to become a scientist when I grow up"). This measure was adapted from existing measure used in prior research (Robnett & Leaper, 2013). There were seven items in total, each representing a STEM-related career: scientist, engineer, science teacher, math teacher, computer programmer, astronaut, doctor (*M* = 2.34, *SD* = .79, α = .82). The correlation coefficient between the first two measurement points suggested that ratings on this measure were fairly stable, *r* = .65.

Maker and science identity. Two variables were assessed to capture students' identification with Making and science as important parts of who they are. Maker identity was measured with a 12-item scale (*M* = 3.32, *SD* = .52, α = .83) adapted from the Maker Mindset

Assessment (The Maker Effect Foundation, 2015) to be suitable for elementary school children. An example item included the following statements: “I like making things with my hands” vs. “I don’t like making things with my hands”. The correlation coefficient between the first two measurement points for this measure was .21. Given that this variable (as well as the variables reported after this) were only measured twice a year (at the beginning and end of the year), this moderate correlation suggests an expected level of rank-order stability. The temporal gap between the two measurement points would be expected to weaken the strength of correlations relative to the measures assessed every week.

We used another single face-valid item to assess science identity: “Being good at science is an important part of who I am” vs. “This is not a very important part of who I am” (*M* = 3.31, *SD* = .92). The correlation coefficient between the first two measurement points for this measure was .19.

STEM possible selves. STEM possible selves were assessed with seven items adapted from Anderman et al. (1999). For these items, students chose between statements that started with “I might have a job where I….” vs. “I probably won’t have a job where I…”. The statements concluded with “help build things”, “discover new things”, “make and invent new things”, “use technology every day”, “uses math” “uses science”, and “uses writing”. The seven items were averaged to form a composite (*M* = 3.02, *SD* = .69, α = .80). The correlation coefficient between the first two measurement points for this measure was .30.

6. Results

We will first present within person correlations among all the study variables, followed by an examination of the changes in the variables across the course of the study using multilevel modelling.

6.1 Within-Person Correlations

Average within-person correlations among study variables are reported in Table 1. As can be seen in the table, all the variables were positively correlated with each other, as might be expected. The strength of the correlations ranges from .09 (weak) to .79 (strong). Correlations within Making-specific, science-specific or STEM-specific variables support the convergent validity of our measures. Of particular interest are the correlations between the Making-specific variables with the science and more general STEM variables. The degree of these correlations is at least suggestive that Making can be used effectively to facilitate both science and, more broadly STEM, positive self-perceptions.

Table 1. *Average Within-Person Correlations.*

Variable	***Making Self-Efficacy***	***Science Self-Efficacy***	***Making interest***	***Science interest***	***STEM career Interest***	***Maker ID***	***Science ID***	***STEM Possible selves***
Making self-efficacy	-							
Science Self-efficacy	.30	-						
Making interest	.79	.29	-					
Science interest	.27	.42	.32	-				
STEM Career Interest	.19	.22	.17	.09	-			
Maker ID	.43	.23	.40	.28	.19	-		
Science ID	.27	.56	.22	.53	.32	.28	-	
STEM Possible selves	.34	.37	.21	.35	.37	.40	.40	-

6.2 Longitudinal analyses using multilevel modelling

In order to estimate the within-person change over time, we conducted a series of multilevel models (Raudenbush & Bryk, 2002; Snijders & Bosker, 1999). Each of the eight dependent variables was tested in its own model. Level 1 in these models represents the within-person change over time and level 2 represents between-person individual differences. The only predictor included at level 1 was time. No level 2 predictors were included in the first set of models tested.

Time was coded such that 0 represented the pre-test for the academic year that the student first entered the study. Recall that each year includes 8 data collection opportunities: the pre-test at the start of the year, the end of each of the six intervention weeks, and the post-test at the end of the year. Thus, some students who had been in the program for the full two years had as many as 16 waves of data collection across the two years. Multilevel modelling (MLM) accounts for within-person dependence in scores across time and also accommodates unequal numbers of observations and unequal time intervals between the waves of data collection. The amount of "information" any one participant contributes to the model is directly proportional to the number of observations for that participant. MLM fixed-effect estimates can be interpreted similarly to regression coefficients in OLS regression.

In order to check the assumptions of MLM, we followed the parameters outlined in the assumptions chapter (chapter 8) of Snijders and Bosker (1999). We first plotted the means across waves for all variables. For the variables assessed at every survey (not just those at the pre- and post-tests), it seemed that simple linear growth may not be adequate to capture the nature of the changes over time (See Figure 3). As such, we next estimated a model for each of these variables using restricted maximum likelihood that included linear, quadratic, and cubic growth terms. We also examined whether there was significant variability around the slopes in the various models for the different dependent variables. Chi square tests revealed significant variability around most of them (p's < .05; See subsequent results descriptions for more details) and we thus decided to specify our growth terms as random effects. Finally, we also tested all models for violations of homogeneity of level 1 variance and found that all were non-significant (p's > .50), suggesting that the assumption of equal level 1 variances was met in all models. Given that our primary results did not involve any level 2 predictors, other assumptions did not apply in this case. Finally, in order to obtain effect sizes we followed guidelines from Rosnow, Rosenthal, and Rubin (2000; Equation 2.5), and used the obtained *t* and *df* to calculate effect size *r* coefficients.

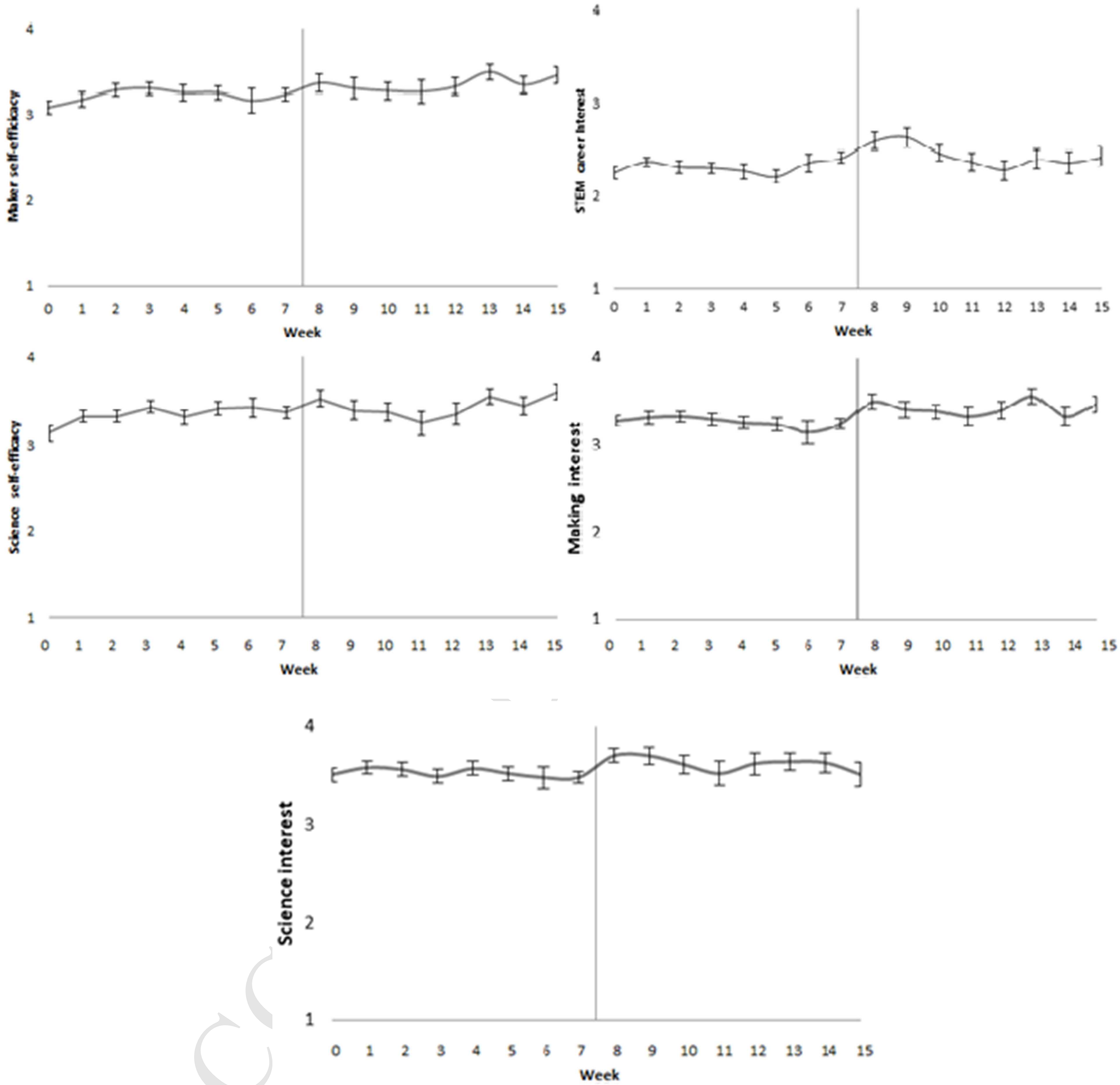


Figure 3. Means of Maker Self-Efficacy, Science Self-efficacy, STEM Career Interest, Making Interest and Science Interest over time.

Note. Weeks 0 and 7 were pre-test surveys, weeks 8 and 15 were post-test surveys, all other weeks were end of week surveys following an intervention week. Weeks on the left of the central line represent the first year the student was in the program; weeks on the right of the central line represent the second year the student was in the program. Error bar represents ±1 standard error of mean.

Table 2. Results from Polynomial MLM Models

	Beta	**Standard Error**	***T* Ratio**	**DF**	***p* value**	***r***
Polynomial Models						
Making Self-Efficacy						
Linear	.09	.04	2.37	189	.02	.17
Quadratic	-.01	.006	-2.07	189	.04	.15
Cubic	.0006	.0003	2.10	189	.04	.15
Science Self-Efficacy						
Linear	.13	.04	2.97	189	.003	.21
Quadratic	-.02	.01	-2.51	189	.01	.18
Cubic	.0008	.0003	2.44	189	.03	.17
Making Interest						
Linear	-.02	.03	-.66	189	.51	.05
Quadratic	.003	.005	.62	189	.54	.05
Cubic	-.0001	.0002	-.41	189	.68	.03
Science Interest						
Linear	-.03	.03	-.93	188	.36	.07
Quadratic	.007	.006	1.09	188	.28	.09
Cubic	-.0003	.0002	-1.12	188	.56	.09
STEM Career Interest						
Linear	.01	.03	.40	189	.69	.03
Quadratic	.0004	.005	.09	189	.93	.00
Cubic	-.00008	.0002	-.38	189	.71	.03

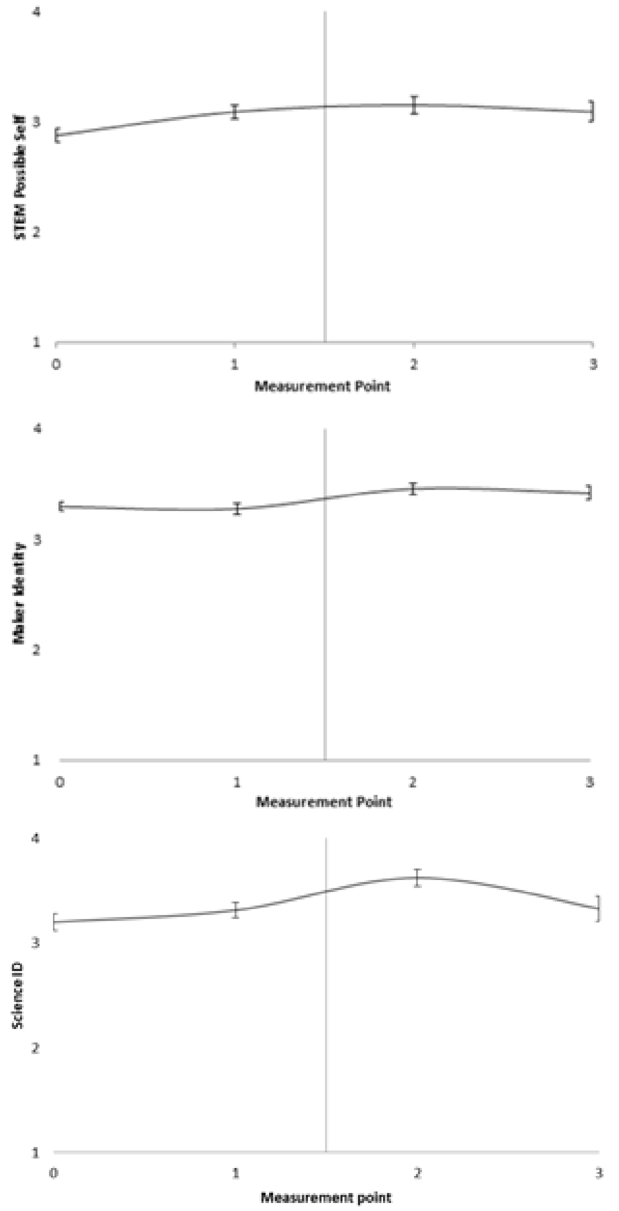
As can be seen in Table 2, a significant upward trajectory was observed for two of five dependent variables (both types of self-efficacy), suggesting that students' self-reported self-efficacy scores significantly increased over the course of the study. For both of the self-efficacy variables, there were also significant quadratic and cubic growth terms. As can be seen in the figures, these terms captured the plateaus at each end of the figures. It is not surprising that the growth was somewhat more nuanced than simple linear growth over the course of the study. Clearly, however, self-efficacy was increasing over the course of the study. Making and science interest did not significantly change over the course of the study nor did STEM career interest. This suggests the positive effects of the intervention were primarily observed through increased self-efficacy in both science and Making (at least among the variables measured every week). Examination of the means in Figure 1 are suggestive that students' self-perceptions might be increasing for other variables as well, but these patterns were not statistically significant. It is also worth noting a ceiling effect among some variables such as science interest. Students started with very high levels of self-reported science interest (year 1 pretest: $M = 3.52$; $SD = .82$). Indeed, nearly 70% of the sample had a score of 4 (i.e. the maximum score) at week 1 on science interest. This left no real room for scores on this variable to improve.

We also examined whether there was significant variability around any of the linear growth terms for the five variables reported in Table 2. Chi square tests revealed significant variability around most of them (p's < .05). The only exceptions were Making interest ($p = .09$) and STEM career interest ($p = .42$). This suggests that there are likely individual differences that influenced the degree of change students experienced over time on these variables. An examination of the correlations between intercepts and slopes on the three variables that had significant variability around the slopes revealed that the biggest gains were seen among students who started at the lowest levels of these variables at the start of the study (r's = -.24, -.62, -.08 for maker self-efficacy, science self-efficacy, and science interest, respectively). This suggests that the Making intervention has the potential to close gaps between students that start at different levels on some efficacy and interest variables. This also helps explain why the test-retest reliabilities were relatively low for the self-efficacy variables. If the intervention is closing gaps, it makes sense that rank order stability is attenuated for these varaibles.

We also tested for possible interactions with race and gender on the three variables that evidenced significant variability around the slopes (i.e., Making self-efficacy, science self-efficacy, and science interest) by including these variables at level 2 in both the intercept and slope equations. There were no significant effects of gender on either intercepts or slopes (all *p*'s > .33). For race, the comparisons were limited to African-American (n = 51) and Latino/Hispanic (n = 132) because there were not enough Caucasian participants (n = 6). These results revealed no significant effects of gender on either intercepts or slopes (all *p*'s > .15).

Recall that we had three other dependent variables that were only assessed at the beginning and end of each school year (maker identity, science identity, STEM possible selves). For these three variables, we again plotted the means (see Figure 4). Given the reduced number of observations, it only makes sense to estimate linear and quadratic growth in the HLM models for these variables.

Figure 4. Actual means for STEM Possible Selves, Academic Identity, and Maker Identity over time.



Note. Measurement points correspond to weeks 0, 7, 8 and 15 (i.e. pre and post surveys). This variable was not measured in end-of-week surveys so other weeks have been removed from Figures 4, 5 and 6. Weeks on the left of the central line represent the first year the student was in the program; weeks on the right of the central line represent the second year the student was in the program. Error bar represents ±1 standard error of mean.

Table 3. Results from the Linear Growth HLM Models.

	Beta	Standard Error	*T* Ratio	DF	*p* value	*r*
Linear Only Models						
Maker Identity						
Linear	-.005	.012	-.40	179	.69	.03
Quadraric	.0008	.0009	.94	179	.34	.07
Science Identity						
Linear	.05	.02	2.09	178	.04	.15
Quadratic	-.0002	.002	--1.55	178	.12	.12
STEM Possible selves						
Linear	.04	.014	2.79	178	.006	.20
Quadratic	-.002	.001	-1.88	178	.061	.14

As can be seen in Table 3, significant linear growth was observed for two of the three variables (science identity and STEM possible selves), suggesting that scores on these two variables increased over time. Maker identity did not change significantly over the course of the study. There were no significant quadratic terms for any of the variables. We also examined whether there was significant variability around any of the linear growth terms for these three variables, and there was not (likely due to the reduced number of observations for these variables; many of the participants only have two waves of data for these variables).[1]

7. Discussion

The current study investigated the trajectory of a host of self-concept-relevant variables in a group of elementary school children who were involved in an intervention that infused Making into their existing science curriculum. We hypothesized that systematic use of Making in a public school context had the potential to shape the self-concepts of these students as it pertains to Making and science specifically, as well as STEM more generally. In the introduction, we

[1]We also conducted a series of within subject t-tests that compared student scores from their first wave of data to their final wave of available data on all dependent variables. These analyses revealed the same patterns. Given that MLM is a more sophisticated analytical approach, we do not report those t-tests in the manuscript. They are available from the authors.

stated that because students constructed their own science experiment tools in the classroom instead of simply being given these tools, their Maker and STEM self-concepts may be affected in some manner. We focused specifically on changes in self-efficacy, interest, and identification with Making and/or science (Making and science were examined separately, creating six possible relevant dependent variables on these dimensions). We further examined more distal potential changes in STEM career interest and STEM possible selves (i.e., two additional possible dependent variables, for a total of eight).

Of these eight potential dependent variables, we observed significant change over time in four of them (i.e., Making self-efficacy, science self-efficacy, science identity, and STEM possible selves). This makes sense given our underlying rationale of integrating Making in the school curricula. Students building their own tools for science over time grow in their sense of self-efficacy (i.e. beliefs about what one can do) of both Making and science, and develop in their estimation that they can possibly do STEM-related tasks in the future (science identity and STEM possible selves, or beliefs about who one might become). While we did not predict a priori this particular pattern of results (i.e. which exact variables may evidence change vs. not), the pattern of results is suggestive as to which variables are most likely to be impacted by infusing technology-based Making into the formal science curriculum in elementary schools. The correlational findings also point to a similar conclusion given that the Making variables evidenced positive correlations with all science and STEM variables. Some of these correlations were fairly substantial, suggesting that changes to Making efficacy may be an effective means by which to influence science and STEM-relevant self-concepts.

The results did not reveal significant changes over time in the four other variables (i.e., Making interest, science interest, Maker identity, STEM career interest). One possible explanation is that while the students increase in their sense of being able to make and do science, they do not necessarily become more interested in Making and/or science. Furthermore, even though they may believe that they can possibly do STEM-related tasks in the future, they do not necessarily identify directly as Makers or scientists as that point of time. Nevertheless, it should be noted that some of these variables (e.g., Making and science interest) were quite high to begin with, thus creating a ceiling effect that left little room for many of the students to grow. There was some indication in the longitudinal analyses that those who scored lowest in these variables at the beginning of the study, evidenced more pronounced growth (as evidenced in the correlation between intercepts and slopes). This suggests that engagement in Making may still be beneficial for these constructs, but future research is clearly needed. As one of the first systematic longitudinal quantitative studies in this literature, all of the results should be considered preliminary and in need of replication. We hesitate to draw too many conclusions about which variables are affected by the intervention vs. not.

It is important to examine what types of educational contexts influence these types of self-perceptions because beliefs about what one is good at (Bandura, 1993) and what is possible for one's self (Cross & Markus, 1991) are important parts of the self-concept, including the self-concepts of children (Cimpian, Hammond, Mazza, & Corry, 2017). Further, self-concepts guide future behavior (Markus & Wurf, 1987, Brummelman & Thomaes, 2017; Schlegel, Hicks, Davis, Hirsch, & Smith, 2013). Instilling positive science and STEM-related identities at this young age has the potential to shape the choices students make about what classes to take and activities to be involved in during middle and high school; choices that, in turn, are likely to influence decisions regarding whether to attend college, what to major in during college if one attends, and what type of career to pursue (e.g., Britner & Pajares, 2001). While the current study cannot speak to what majors or careers these children may pursue in the future, we suspect that positive experiences with technology early in education may "plant a seed" early in one's self-concept that a STEM-related career might be an option in the future. Planting this seed early may be critical. Indeed, we suspect that many similar existing interventions occur too late in the developmental trajectory to plant such seeds (i.e., when self-concepts are already too well formed or crystallized).

While many studies (e.g., Taylor, Castro, & Walls, 2004) have shown the influence of technology infused lessons on learning, this is among the first work that examines the influence of technology-infused lessons on students' self-concepts longitudinally in a systematic fashion. Initial results from the first year of the project (Anonymous, 2017) evidenced similar patterns in a smaller sample over a shorter period of time. Taken together, these two sets of findings converge in their suggestion that experiences with Making can influence children's self-concepts. Importantly, these findings emerged among students who are traditionally underrepresented in STEM fields and thus less likely to form STEM possible selves in other ways (e.g., there are fewer role models that look like them, less access to STEM programs outside of school that are often cost prohibitive). Psychological constructs have often been studied as one of the major causes of the achievement gap in STEM between majority and minority student populations (Williams, 2011). Thus, our empirical evidence is particularly impactful in that it shows engagement in Making-based experiences in authentic science school classes helps minority students to form positive formative STEM-related self perceptions.

7.1 Limitations

The current research has several limitations that warrant further attention. First, as mentioned earlier, we deployed our intervention every six weeks over an academic year. Some variables were measured every six weeks, others were measured even less frequently (twice a year). With such a gap in time, it is possible that extraneous variables (e.g. dynamics associated with school or family environments) may introduce additional sources of errors into our measures and their estimated trajectories over time.

Second, our focal school is relatively homogeneous in terms of SES and racial background (e.g., almost 75% Latino). While these populations tend to be under presented both in research and in STEM fields, it remains an open question whether our intervention will be equally effective with other groups. It is also an open question whether the intervention would function differently in schools with a more heterogeneous student population. Indeed, racial identity might be more salient in heterogeneous schools and this may influence science and STEM identities differently.

Third, there were a number of limitations in the measures we used. For example, some of our measures (e.g. academic interest, Maker identity) evidenced a fair amount of instability over time. As mentioned previously, some of this instability is likely explained by relatively large gaps in time between measures (as much as an entire school year in some cases). Generally speaking, measures tend to be less stable the longer the period of time between administrations. We also know from the longitudinal analyses that students who started with lower scores gained the most from the intervention; this may be another source of the instability. Further, almost all of our variables were negatively skewed with a restricted range. For example, let's consider science self-efficacy. At Wave 1, 48.4% of students reported a maximum of 4 on science self-efficacy. By wave 2, this number was already climbing to 53.8%. By Wave 15, 70% of students are reporting a maximum of 4. Such patterns are consistent with the idea that the intervention is closing gaps and thus rank order stability would be expected to be relatively low. Finally, it is also possible that children's understanding of what "science", "Making" and "STEM" are changing over time (from pre-survey to post-survey), children might have gained new understanding (e.g. about what "science" is) and this causes some instability. Future research should examine such issues. Finally, the use of single item measures for some variables is a limitation in and of itself. While single item measures are generally to be avoided, they are sometimes necessary in a context such as this. We had limited time to administer the weekly surveys in the context of an active classroom and had to make some difficult choices about our measures. While any analyses using single item measures should be interpreted with some caution, we note that there is some evidence within the study for the validity of these measures (i.e., face validity, the positive correlations with similar constructs measured with multi-item measures, and the similar trajectory over time as the multi item measures). Nonetheless, future research should clearly aim to replicate these patterns with more complete measures. Indeed, the current results may help future researchers "hone in" on key variables that can be measured more completely within a limited time as opposed to trying to assess as many variables as the current study did.

A fourth concern with the current findings is that the lack of a control group makes it difficult to definitively infer causation. Indeed, it is possible that all students evidence growth on these variables over the course of schooling. While we cannot rule out this interpretation, it is worth noting that our previous work over a shorter period of time (Anonymous, 2017) has demonstrated differences from a control group over the course of a single academic year. Of course, there may also be demand effects. To the extent that the children received education in Making for as much as two years, they might feel inclined to report greater efficacy over time. We think this explanation is plausible for the Making efficacy variable, but seems less relevant to the science efficacy and STEM possible selves variables. It is not clear that the students would have any idea that the intervention was meant to target these variables. The fact that not all variables evidenced change also suggests that there was some specificity to the effects observed, further speaking against demand effects.

Last, it is worth noting that the current findings are based entirely on self-report measures. The usage of self-report measures is a common practice in study of constructs like self-efficacy (see for example, Bandura, 2006). Nevertheless, self-report measures are known to be vulnerable to various sources of biases, such as social desirability. In the context of the current research, these biases could wash away some of the effects we were after (e.g. academic interest and STEM career interest). In particular, social desirability may account for the uniformly high levels of science interest students reported. Future research could also further our quest by including measures that are not based on students' self-reports (e.g. teachers' or parents' observations of students) or by examining downstream consequences of the intervention (e.g. students' GPA in relevant fields or interests in STEM beyond class).

8. Conclusion

Despite its limitations, the current work provided important insights of how Making can factor into the early stage of self-efficacy and STEM possible selves. We integrated Making into existing elementary science curricula and deployed the intervention among school children from groups traditionally underrepresented in STEM fields in the formal classroom of a public school. We then evaluated the impact of the program over a two-year period. The results provide empirical evidence that technology-infused learning as facilitated by Making can foster the development of self-efficacy and STEM possible selves at an early age. Given the potential of these identities in shaping future choices, we hope that our work can help to inform understanding in terms of the impact of Maker programs and contribute to their adaptation into a broad variety of school settings.

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Appendix A. Sample Maker Lesson plan

The lesson plan below is for Day 1 of the Maker week for 5th grade on the topic of 'Solar System'. Lesson plans are created for each day of the Maker week.

MATERIALS NEEDED

LEDs, laptop, Arduinos, tape, busses, lampshades, (Two groups per table work together), Maker Lab journal, pencil

SCIENCE OBJECTIVE

The student will learn the sequence, names, and characteristics of the planets in the solar system.

MAKING OBJECTIVE

The student will construct parallel circuits and illuminate LEDs in sequence using Arduino and Ardublockly.

PHASE 1: INSTRUCTION

Teacher: Who can name the planets in our solar system?

[Elicit student response. Try to keep each response to a single planet name, to allow more students a chance to respond.

Be prepared for answers to include non-planets such as "Pluto".

(T: "That's in our solar system, but it's not a planet," etc. *May address that Pluto used to be considered a planet, but scientists decided it was too small to be a planet and is now called a "dwarf planet". There are five known dwarf planets in our solar system: Pluto, Ceres, Eris, Makemake, and Haumea.*)

Write answers on the board to make sure they are all included.

With answers recorded, ask students which planet is closest to the sun. Reorganize list until all eight planets are listed in order from nearest the sun to furthest away. 5th grade is likely to have supplied planet names in the correct order, so more detailed questions may be asked:

(e.g. Which planet is largest? Between what planets' orbits is the asteroid belt located? Where can we find the Kuiper belt? Which planet has the most moons?]

Teacher: Now we are going to make a model to show the order of the planets.

PHASE 2: COLLECTING MATERIALS

Each group will collect LEDs, laptop, Arduino, tape, busses, lampshades, Maker Lab journal, pencil.

PHASE 3: BUILDING INSTRUCTION

Teacher should review the use of busses to create parallel circuits. Two groups per table will split the 8 planets between them and will work together to create a sequence that lights up one planet at a time.

PHASE 4: MAKING

Students will assemble their circuits and place the lampshades in correct sequence, then demonstrate lighting up each LED in sequence.

PHASE 5: JOURNALING

Teacher may take the opportunity to introduce more characteristics of the planets, such as asking students to illuminate the largest planet, all planets with rings, the planet where things can live, or the planet that is the same size as Earth. Students will be able to discuss among their groups and reach a consensus.

(5 mins)

Use a few minutes of class to have students discuss what they understood and what they didn't. Students should record the order of the planets in their journals in addition to drawing the circuits they constructed.

Appendix B. Final Survey Items for Each Variable

Maker Self-efficacy

Really True for me	**Sort of True for me**				**Sort of True for me**	**Reall y True for me**
☐	☐	I **am good at** building or making things	**OR**	I'm **not very good at** building or making things	☐	☐

Science Self-efficacy

Really True for me	**Sort of True for me**				**Sort of True for me**	**Reall y True for me**
☐	☐	I feel I am very good at **science**	**OR**	I worry whether I can do the assigned science work	☐	☐

Making Interest

	Really True for me	Sort of True for me				Sort of True for me	Reall y True for me
	☐	☐	I **like to** build or make things	**OR**	I **don't really like to** build or make things	☐	☐

Science Interest

	Really True for me	Sort of True for me				Sort of True for me	Reall y True for me
	☐	☐	I like **science**	**OR**	I don't like science	☐	☐

STEM Career Interest

	Really True for me	Sort of True for me				Sort of True for me	Really True for me
1.	☐	☐	I want to become a **scientist** when I grow up	**OR**	I <u>do not</u> want to become a **scientist** when I grow up.	☐	☐
2.	☐	☐	I want to become an **engineer** when I grow up	**OR**	I <u>do not</u> want to become an **engineer** when I grow up.	☐	☐
3.	☐	☐	I want to become a **science teacher** when I grow up	**OR**	I <u>do not</u> want to become a **science teacher** when I grow up.	☐	☐
4.	☐	☐	I want to become a **math teacher** when I grow up	**OR**	I <u>do not</u> want to become a **math teacher** when I grow up.	☐	☐
5.	☐	☐	I want to become a **computer programmer** when I grow up	**OR**	I <u>do not</u> want to become a **computer programmer** when I grow up.	☐	☐
6.	☐	☐	I want to become an **astronaut** when I grow up	**OR**	I <u>do not</u> want to become an **astronaut** when I grow up.	☐	☐
7.	☐	☐	I want to become a **doctor** when I grow up	**OR**	I <u>do not</u> want to become a **doctor** when I grow up.	☐	☐

Maker Identity

Really True for me	Sort of True for me				Sort of True for me	Really True for me
☐	☐	I like making things with my hands	**OR**	I don't like making things with my hands	☐	☐
☐	☐	I like learning about new things	**OR**	I don't really like learning new things	☐	☐
☐	☐	I am creative	**OR**	I am not very creative	☐	☐
☐	☐	I am willing to help other people	**OR**	I don't like to help other people	☐	☐
☐	☐	I like to share things I make with other people	**OR**	I don't really like to share the things I make	☐	☐
☐	☐	I like to try building things with different materials	**OR**	I'm not really interested in building things	☐	☐
☐	☐	I know a lot about technology	**OR**	I'm not very good with technology	☐	☐
. ☐	☐	I do things even if I am not sure I will get it right	**OR**	I only do things if I know I will get them right	☐	☐
☐	☐	When something goes wrong, I keep trying	**OR**	When something goes wrong, I stop trying	☐	☐
☐	☐	I like to work in groups	**OR**	I don't like to work in groups	☐	☐
☐	☐	I can do things on my own	**OR**	I have trouble doing things on my own	☐	☐
☐	☐	I think that I am good at a lot of things	**OR**	I am not good at very many things	☐	☐

Science Identity

	Really True for me	Sort of True for me				Sort of True for me	Reall y True for me
	☐	☐	Being **good at science** is an important part of who I am	**OR**	This is not a very important part of who I am	☐	☐

STEM Possible Selves

Really True for me	Sort of True for me				Sort of True for me	Really True for me
☐	☐	Someday I might have a job where I help **build things**	**OR**	I probably won't have a job where I help build things	☐	☐
☐	☐	Someday I might have a job that **uses math**	**OR**	I probably won't have a job that uses math	☐	☐
☐	☐	Someday I might have a job that **uses science**	**OR**	I probably won't have a job that uses science	☐	☐
☐	☐	Someday I might have a job that **uses writing**	**OR**	I probably won't have a job that uses writing	☐	☐
☐	☐	Someday I might have a job where I **discover new things**	**OR**	I probably won't have a job where I discover new things	☐	☐
☐	☐	Someday I might have a job where I **make and invent new things**	**OR**	I probably won't have a job where I make and invent new things	☐	☐
☐	☐	Someday I might have a job where I **use technology** every day	**OR**	I probably won't have a job where I use technology every day	☐	☐

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Highlights

Making-based science curriculum deployed for two years in a public elementary school

Significant increases in Making and science self-efficacy, and STEM possible selves

Utility of Making in science curricula on identity among underrepresented students