'I Make, Therefore I Am': The Effects of Curriculum-Aligned Making on Children's Self-Identity

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ABSTRACT
Prior research investigating the effects of incorporating Making into educational contexts has been limited to snapshot studies. These studies however do not allow for the investigation of aspects that require longer-term development and nurture. We present a longitudinal study that investigates the effects of Making on children's degree of science self-efficacy, identity formation as possible scientists and engineers, and academic performance in science. Designed interactions with Making technology were integrated into the science curriculum of elementary school classrooms in a public school with a high proportion of students from minority populations for a year. Results showed significant differences between the 'Making classrooms' and the control classrooms, and from pre- to post-test on the students' inclination towards science. The results support the promise and potential of incorporating Making into formal schooling on the growth and long-term attitudes of children towards science and STEM in general.

Author Keywords
Making; Maker movement; Children; Education; STEM; Science; Self-identity; Self-efficacy; Learning.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
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 creation of technology-based artifacts. It is typically associated with values and characteristics such as play, innovation, intrinsic motivation [1] and technological literacy. Many have commented on the potential for Making to support, enliven, change, or even revolutionize children's education in subjects such as science, mathematics and computing.

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A challenge to the use of Making in formal education is that while Making emphasizes and values discovery and innovation, modern public school systems are driven by scheduled learning goals and accountability [2]. Hence, most Making-oriented programs are conducted in such venues as workshops, community-based Makerspaces, museums, after-school programs, and paid Maker classes. This poses issues of equity as participants are self-selected through parents who see the value of Making, and have the resources to bring their children to these venues.

This paper presents results from a quantitative analysis of variables and interactions of a year-long Making-oriented program implemented in a low socio-economic status public elementary school that serves students from predominantly underrepresented populations. The students engaged in Making activities designed to match their state-mandated existing science curriculum. Our results how our program was related to students' self-efficacy, interest and identity in Making and STEM (Science, Technology, Engineering and Mathematics).

To date, there have been few studies to validate the promise advanced for HCI research in Making, and even fewer have looked at sustained application of Making for the broader population within the framework of public schools that support universal access to learning and development. Insofar as work in HCI is growing rapidly on the design of Maker kits (e.g., Mentjes and Schelhowe's work at the Interaction Design and Children conference 2016 [3]), understanding motivations of Makers (e.g., Hudson et al.'s work in CHI 2016 [4]), the study of Maker cultures (e.g., Lindtner et al.'s work [5] and Taylor et al.'s work [6] in CHI 2016), etc., this paper contributes empirical evidence on the potential impact of Making, thus cementing the 'raison-d'être' of or rationale for such HCI work in Making.

We lead into the rest of this paper with a review of work on Making in education. Our review first describes theoretically and empirically the role of Making in learning, and then overviews investigations that have broached the issue of self-efficacy and self-identity in Making in learning contexts. We then present the theoretical foundation for our work, before describing our study, measures, analysis procedures, and results.

BACKGROUND: MAKING IN EDUCATION
Much has been written about the role of Making in learning. A significant portion of prior work has been in

terms of practical industry and government initiatives. For instance, programs have combined craft technologies with engineering and mathematics education [7], the Laboratory School for Advanced Manufacturing (Lab School), grounded in the premise that students can learn through the design and fabrication process [8], or the FabLab@School worldwide network that allow children to solve their own and the local community problems by making the tools they need [9]. Theoretically, Making and digital fabrication in education have been said to be founded on Papert's constructionism [10] – hands-on learning through the creation of digital and physical artifacts.

However, the integration of Making in learning is challenging. For example, drawing from his observations in digital fabrication workshops with older students, Blikstein [10] reports on the 'keychain syndrome': equipment are trivialized when over time, students become fixated on using them for making only one thing (keychains in his case). Nemorin [11] draws from his ethnographic experiences in 3D printing workshop classes to highlight three issues that may be problematic for the integration of Making into formal schooling: 1) the lack of pragmatic engagement, 2) affective labor, and 3) mediated alienation. Much evidence that show the benefits of Making with regards to learning in the literature is qualitative in nature. In the only published survey paper on empirical studies of Making to date, Papavlasopoulou et al.'s [12] analysis of the 43 studies that met their selection criteria revealed that the majority of the studies (52%) were qualitative, with the rest being either mixed (30%) or purely quantitative (18%). They noted that most of the quantitative studies measured the results of the treatment only through a post-test. Their review also showed that most of the studies had a sample size that was fewer than 50 participants.

Even so, qualitative Making for learning studies reveal that students' experiences in Making scenarios are rich, multi-layered and complex. Flores and Springer [13], for instance, describe the initial experiences of students who followed an inquiry-based curriculum at the Hillbrook Middle School Makerspace. Posch and Fitzpatrick [14] report case study experiences of children aged 10 to 14 years old who attended a workshop at a FabLab that provided instruction on 2D/3D design and fabrication, printed circuit board (PCB) fabrication and assembly, and software programming. Sheridan et al. [15] present a qualitative analysis of the processes that occur in three different Makerspaces when taken as learning environments. Worsley's [16] doctoral dissertation presents results from multimodal analyses of high school and tertiary students engaging in various Making-related activities, with an emphasis on the analysis of reasoning strategies used. Nemorin and Selwyn [17] present an ethnographic investigation of a 3D printing course enacted in an Australian high school.

Existing quantitative results that we found on Making for learning are encouraging. For example, in the Robot Diaries project [18, 19], middle school students designed "affective, programmable tangible communication devices using familiar crafting materials and then use motors, lights and computation in novel ways to animate their creations". The project was tested in a six-day workshop with seven participants. Pre-post tests show that the children improved in both declarative knowledge and general knowledge of technical systems. They identified and correctly labeled on average 4 out of 6 robotic components at pre-test and 5.9 at post-test. More children were able to better identify the parts of a given electronic toy and explain how it works at post-test than at pre-test.

Work on Making in educational settings is growing rapidly, and it can be ascertained from the literature thus far that Making is somewhat positively correlated with the learning of specific subject matter. However, a gap still exists in our understanding of the longer-term effects of Making approaches, especially in formal learning contexts. This gap in knowledge is echoed in Jenkins and Bogost's [20] lament that HCI Making research is hermetic and isolated from the broader world of domain practice. We argue that with a greater focus on the development of the person – the Maker – rather than simply on technology kit development or the transfer of content and skills, HCI Making research can contribute significantly to the development of Makers who have the appropriate mindset and predispositions to venture outside the artificial confines of Maker workshops and planned activities.

THEORETICAL FOUNDATION

Development of a Maker Identity

Literature in Making research that specifically addresses identity or mindset formation is scarce. Halverson and Sheridan [21] define Makers as the "identities of participation that people take on within the Maker movement". What characterizes a Maker identity or who is a Maker? Based on interviews with 17 youth about their conceptions of themselves as Makers, Martin and Dixon [22] put forth that Maker youth espouse 3 themes: "Open community, Active participation"; "Making in control to the normal"; and "Making is integrated across all contexts". Six experts conducted in-depth interviews to construct Maker profiles of the youth presenters of 5 showcased projects at the 2012 World Maker Faire [23], and the profiles show characteristics that echo many of the values identified by others in the adult Maker. In a survey of 2600 adults participating in a range of DIY communities, Kuznetsov and Paulos [24] identified 'open sharing', 'learning', and 'creativity' as important values of the Maker. Based on their ethnographic studies of steampunk practitioners, Tanenbaum et al. [25] highlight 'pleasure', 'utility' and 'expressiveness' as values in the Maker movement. Further, Dougherty has aligned the Maker mindset with the 'growth mindset', a mindset that tolerates risk and failure, and that believes that capabilities can be developed instead of being fixed.

Thus, if a Maker is creative, learning-oriented, open to sharing, risk-taking, and tolerant of failure, does one's engagement in Making impact one's sense of self to incorporate a Maker identity? The answer is not evident as engagement in Making may not lead one to become a Maker, just as anyone can engage in cooking but may not fashion themselves to be cooks. Halverson and Sheridan [21] state it as such: "it is not clear that individuals and groups automatically take on identities of participation within the Maker landscape. Some participants in Making activities may not consider themselves Makers and therefore self-select out of public conversations".

More importantly for our work, *can curriculum-aligned Making in the formal public school context in the United States impact children's identity as a Maker?* The difficulty that formal school contexts add is at least two-fold: first, the characteristics of Making and of the Maker tend to be counter to schooling cultures and frameworks, and second, in the classroom the goal of the teacher is to teach about the specific topic or subject matter of the class (science, language arts, history, etc.). What then is the role of Making in such contexts, and by which pathways may a Maker identity be fostered? Although the constraint of topic learning, e.g., science, is not necessarily present in short-term studies done in informal contexts, such studies have provided indications of potential Maker identity formation through the pathways of increased self-efficacy and interest.

For instance, Katterfeldt et al. [26] draw from decade-long research on digital fabrication workshops for children to present three core ideas that may facilitate Bildung (deep, sustainable learning that leads to 'learning-to-be'): *be-greifbarkeit* (being 'graspable'), *imagineering* (creative approaches to technology), and *self-efficacy* (relating oneself to technology). Qiu et al. [27] conducted three workshops involving middle- and high-school-aged children engaging in computational textiles projects using LilyPad Arduino-based technologies, following a curriculum emphasizing computer science (programming) concepts. They found that the children's perceived self-efficacy increased from pre- to post-surveys on statements such as "I feel comfortable programming computers on my own." The statements however were not drawn from validated scales.

Ornelas et al. [28] present comments that seem to indicate increased technological awareness and confidence in high school students who participated in an afterschool program at the Stanford University FabLab where they engaged in Making and digital fabrication projects. Our own work [29] presenting the approach of a 'means-to-an-end' to integrate Making with learning, has shown that Making has the potential to impact the development of a Maker mindset in a series of workshops with elementary school-aged children. The only longer-term study of Making that we found is Alexander et al.'s [30] who implemented learning activities centered on digital fabrication in 2 fourth-grade and 3 fifth-grade classes across 2 schools for a year. They found that student attitudes were positive in the post-test survey items as compared to the pre-test.

Other studies also suggest that there may be differences in gender in how Making impacts Maker identity formation. Holbert [31] for example, frames Making as being about creating for others, and conducted a five-day workshop with 9 children aged 9 to 10 making 'dream toys' for young PreK children at the same school. The post-interview showed that the children were generally excited about making toys for other children, but findings showed a slight difference between the attitudes of girls versus boys, who "seemed more driven by a personal connection to the toy than to the preK children".

Identity Formation in Science

While theory on Maker identity development is still in its infancy, significant work in social and educational psychology has explored the development of children's motivations and identity development in STEM fields:

Self-efficacy refers to evaluations of one's ability in a given domain [32-34]. A large body of evidence indicates that these evaluations are predictive of many important psychological and educational outcomes. An early study by Bandura and Schunk [35] found that self-efficacy in mathematics was predictive of both objective math performance and self-reported interest in math among 7- to 10-year-olds. More recent work has found that children's self-efficacy is a major predictor of their career aspirations, and the impact of many other factors such as family socio-economic status appears to be mediated by children's self-efficacy [36]. In a similar vein, Wang [37] found that math self-efficacy was predictive of students' decisions to pursue STEM majors in college.

There are biases in terms of race and gender in such science identity development pathways. For example, although many girls express interest in science during their elementary school years, they have increasingly negative views of science, science classes, and science-based careers as they progress through middle and high school [38, 39]. Thus, early self-efficacy in STEM domains seems to be critical to promoting long-term interest and persistence in STEM fields. The period of third- to fifth-grade that we address in our work falls precisely during what Piaget [40] called the 'concrete operational phase', a time when children's social awareness is intensively developing and concepts of self begin to form.

Self-Identification and Self-Concept: Osborne [41] defines self-identification as "the extent to which an individual defines the self through a role or performance in a particular domain." In other words, self-identification refers to the extent to which a person considers the domain in question (STEM, in our case) to be an important and defining part of who they are (their self-concept). A range of theories in social psychology, e.g., cognitive dissonance [42], control theory [43], self-discrepancy [44], self-verification [45], and prototype matching [46], maintain that the self-concept serves an organizing function, such that people generally strive to avoid behaving in ways that are inconsistent with it. Specific to STEM fields, evidence indicates that a major reason for students' lack of interest in STEM is attributable to a dissimilarity between students' own self-concepts and their prototypical concepts of students who like math and science [47]. In other words, a major barrier to student engagement with STEM seems to be that many students simply do not see themselves as the "kind of person" who is interested in STEM fields.

Identity in Making and Science

We put forth that conversely to other kinds of intervention such as curricular changes, teaching strategies, use of novel devices like tablets and Smartboards, etc., the characteristics of Making afford tremendous potential to impact identities, for example: i) Making is hands-on and production-based, and thus require engagement. Many studies have reported on children who continue Making beyond the workshop time allotted (e.g., [48]); ii) Making is integrative. Making projects are not focused on the learning of one specific skill but are cumulative and build upon each other, so that over time the child has greater opportunity to feel that they are approaching mastery; and iii) Making is personal. The 'low threshold, high ceiling' [49] aspect of Making (low barrier of entry with wide possibilities) allows one to easily customize projects. In the words of Kafai, Fields and Searle [50], "the aesthetic component of making affords students the opportunity to bring personal identity into the typically technocratic work of schooling".

In the context of the public school classroom, we hypothesize that a Making intervention will foster students' sense of self-efficacy in Making, and that this increased self-efficacy may in turn cement greater self-identification as a Maker. We also hypothesize that simultaneously, a Making intervention will have positive impact on students' relation with the subject matter of the Making, in our case STEM. The positive impact can be in terms of increased self-efficacy in STEM, which may foster students' self-identification as possible scientists and engineers (or other STEM-related persons), and possibly affecting downstream outcomes such as the students' desire to enter STEM fields.

CURRICULUM-ALIGNED MAKING ACTIVITIES

Our investigation of Making in formal school contexts has necessitated the development of Making kits and activities to be used as part of our Making intervention. We developed 23 Making kits and activities targeted at grades 3, 4 and 5 over the course of a year-long study. The kits and activities were developed by a design team consisting of members with expertise in electrical engineering, computer science, child-computer interaction and design, and education and classroom pedagogy, informed by feedback from the participating teachers. In all the kits, Making was implemented using an interactive arts-and-craft approach in which the students construct their science projects around basic electronic circuits.

Admittedly, prior work in Making has produced a diversity of Maker kits and Making-based implementations tested in workshops or camp settings, e.g., LightUp [49], the MakerCart [51], Chibitronics [52]. Nevertheless, we were interested in Maker kits that are directly aligned with the local curriculum standards, for both pedagogical and practical reasons, thus warranting the development of our own Maker kits. We acknowledge here that, as highlighted by Halverson and Sheridan [21], many questions still remain as to 'what works' for learning through Making, such as "What should students do there (makerspaces)? Should Making supplement current curricula or replace it?". Since the focus of this paper is not to discuss the design of Maker activities in the classroom, we present study results only in the context of our specific Maker kits designed to be aligned with elementary school curricula. We have described the design process of our Maker kits in more detail elsewhere (see [53]). For context in this paper, we present below two examples of the curriculum-aligned Making activities that were deployed in the classrooms.

Example 1:

The first Making week for Grade 5 addressed the science unit of 'Matter and Energy: Mixtures and Solutions'. Specifically, the learning goals of the unit were for students to understand that some mixtures maintain physical properties of their ingredients, such as iron filings and sand, while in solutions, such as salt or Kool-Aid in water, the process of dissolving makes the constitutions harder to separate. On day 1 of the Making week, the students built an electronic mixer (Figure 1 Day 1). The mixer comprised of a basic electronic circuit with a geared rotating motor as the load and a switch made out of card stock and conductive copper tape. A 3D-printed mixer head was attached to the motor through a dowel rod so that the student can insert the head into a container and activate the motor. With their electronic mixer, students mixed glitter with water and made observations about the mixture.

On day 2, the students built an electric sifting tool to separate the individual parts of a mixture (Figure 1 Day 2). This comprised of a simple hand-held sieve with a vibrating motor attached to it. Activating the vibrating motor by depressing the card switch would shake the sieve to separate its contents. On day 3, they built a circuit with a vibrating motor attached to a plastic cup containing glitter and Lego pieces (Figure 1 Day 3). Pressing the switch activates the motor that vibrates the cup, presenting an alternate way to create mixtures. On day 4, the students first constructed their vibrating motor circuit again, and then mixed iron fillings with glitter. They were then tasked to separate the iron fillings from the glitter using a magnet (Figure 1 Day 4). On day 5, the last day of the Making week for the 'Mixtures & Solutions' unit, the students built the same electronic mixer again with the rotational motor circuit, and mixed red Kool-Aid powder with water. They recorded observations on the properties of the solution.

Example 2:

In week 3, the Grade 4 classes engaged in a Making activity aligned with the science unit of 'Earth and Space: Rapid Changes'. The learning goals for the Making week for that unit were to understand that Earth consists of natural resources, its surface is constantly changing, and some changes occur rapidly. Examples of rapid changes include volcanic eruptions, earthquakes, and landslides. The students built a model of a village that sits on a pair of foam-core 'tectonic plates' with vibrating motors attached to its foundations (the plates were placed together in a large plastic box on dowel rod 'pillars' that were attached to the plates with 3D-printed mountings) (see Figure 2). A layer of kitty litter was laid on top of the foam core plates and the students created a village made of decorated origami houses on top of the kitty litter. When the vibrating motors taped to the 'foundation pillars' are activated, the foam-core plates shake and separate, destroying the village and causing some of the kitty litter to fall into the crack of the separated plates. Figure 2 Right shows the students constructing the tectonic plate model.

Other examples of Making activities that the students engaged in included building LED-embedded food chains (see Figure 3 Left), rotating solar system models (see Figure 3 Right), lighted dioramas, reflection and refraction through LEDs, etc.

STUDY DESCRIPTION

Research Questions

The work presented in this paper addressed the following specific questions:

a. *Can Making activities integrated in formal schooling positively influence elementary school students' sense of self-efficacy in Making, interest in Making, and sense of identity as Makers?*
b. *Can Making activities in formal schooling positively influence elementary school students' sense of science self-efficacy, interest in science, and intended career paths?*
c. *Can student participation in curriculum-integrated Making activities positively influence elementary school students' academic performance?*

Study Population

Our study followed third-, fourth-, and fifth-grade classrooms (students aged 8 to 11 years old) of a local elementary school. With consultation from the school's administration, two classes for each grade were selected yielding a total of six classes. The population of the school consists of a majority of students from groups typically underrepresented in STEM fields (72% Latino, 26%

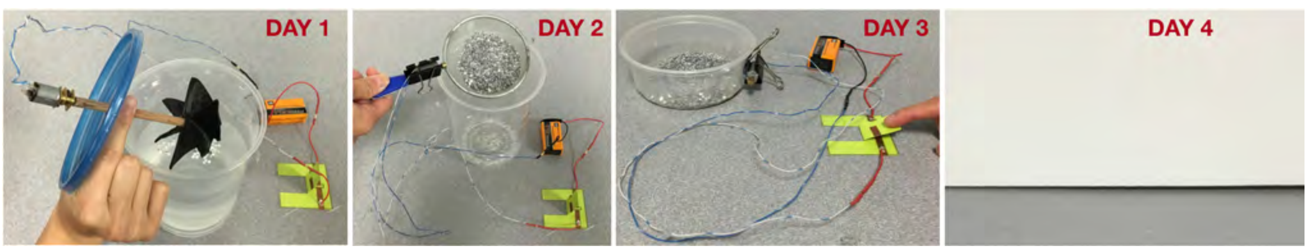

Figure 1. Day-by-day curriculum activities for 'Mixtures & Solutions' Making kit

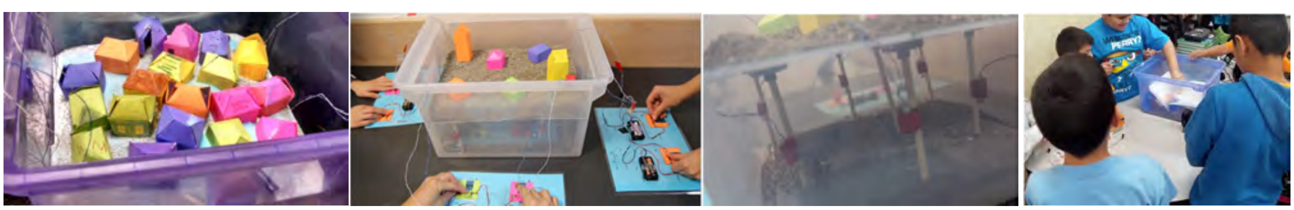

Figure 2. 'Earthquake' Making kit and activity

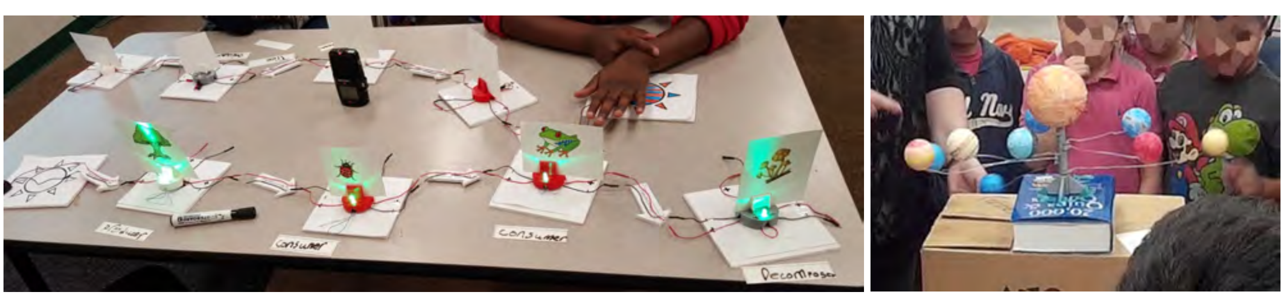

Figure 3. (Left) LED-embedded food chain; (Right) Rotating solar system model

African American, 96% on reduced lunch programs, >50% Low-English Proficiency). We designed and implemented different Making activities centered on specific learning standards for each grade level for every science unit throughout a 36-week school year. The school system covers six science units over a year in accordance with the state's curriculum. In consultation with the teachers, one week was chosen as the Making intervention week for each of the six science units for each grade. We met with the teachers for each class six weeks prior to the designated week that we would be implementing the interactive Making activities in their classroom to engage them as design informants. In total thus, we worked with six teachers and 121 students across the three grades in our intervention. We also administered surveys at the end of the year to students in the unselected classes (n = 3) to serve as a control group (n = 117 students).

Study Protocol

At the beginning of the academic year, parents provided written informed consent for their child to be observed and recorded during class. A pre-survey questionnaire was administered to the students in all participating classes (n = 114: 63% Hispanic or Latino, 35% Black, <1% Multiracial, <1% White) to evaluate their initial predispositions towards Making and towards science. The same post-survey questionnaire was again administered in the last week of the academic year to all students who remained in the study. Furthermore, for each grade level, the post-test was also collected from the classes who did not participate in the study to act as a control group (n = 61). We were unable to collect pre-test data from this control group because of time constraints in the school.

The science class on each day of the Making week consisted of five main parts: i) initial instruction by the teacher; ii) Making instructions by a member of the design/research team; iii) students' engagement in Making; iv) science experiment; v) post-experiment notetaking and discussion led by either the teacher or the researcher. In the initial instruction, the teacher reviewed content previously covered, and introduced the students to the science concepts of the day. The researcher then took over the class to provide guidance as to how to build the artifact, materials needed, and how the artifact were to be used in the science experiment to be performed. Outside of instruction times during the class, the students were allowed to work relatively autonomously and in free-flow interactions. They were able to ask for help from one or two logistics helpers who were present in the classroom throughout the Making process. The teacher or the researcher provided instruction for the science experiment, after which the students were asked to write down their observations in their notebook, and a classwide discussion was initiated. Figure 4 shows the students engaging in one of the Making activities, as well as the general setup of the classroom during the study.

MEASURES

For our study, we focused on the variables of interest, self-efficacy and self-identity with regard to Making and science, as well as academic performance in science, as measured by state test scores. The general format of the pre- and post-surveys was adapted from The Self Perception Profile for Children (SPPC) [54]. In a "structured alternative format", each child was presented with an affirmative statement about themselves and its negative counterpart. The students were instructed to make an initial choice between the two statements, then they were asked to rate how true the statement chosen was of them (see table 1 for an example). Responses were recoded into a 1 to 4 Likert scale type response, such that higher numbers always indicated more interest, efficacy, and identification. We describe below the sources of our measures for each variable.

Table 1. Sample item used in the surveys

Really true of me	Sort of true of me				Sort of true of me	Really true of me
☐	☐	I want to build or make things	OR	I don't really want to build or make things	☐	☐

Maker identity, Self-efficacy and Interest

Maker identity was measured with a 12-item scale (α = .48 in pre-test; α = .89 in post-test). The items in the scale were drawn from the Maker Mindset Assessment [55], and were adapted for elementary school-aged children. An example item included the following statements "I like making things with my hands" and "I don't like making things with my hands". *Maker self-efficacy* was measured by one item we developed based on guidelines specified by Bandura [56] for self-efficacy measures. The two statements in this item read, "I am good at building or making things" and "I'm not very good at building or making things". For *Maker interest*, we developed two items with affirmative statements such as "I like to build or make things" and "I want to build or make things". The two items were significantly correlated (r = .48 in pre-test; r = .60 in post-test), and were collapsed into a single composite.

Science Self-efficacy and Interest

As with Maker self-efficacy, science self-efficacy was similarly measured with two items, with the affirmative statement of the items reading:" I feel I am very good at science" and "Being good at science is an important part of who I am". The two items were again positively correlated (correlation coefficient r = .29 in pre-test; r = .59 in post-test), and collapsed into a single composite.

To measure science interest, we developed another face valid single item measure. The affirmative statement of the item read: "I like science".

STEM Career Possible Self and Interest

Following the work of Anderman et al. [57], we assessed children's STEM career possible self by having them report how true it would be that someday they might have a job where they "help build things", "discover new things", "make and invent new things", "use technology every day", and also a job that uses "math", "science", "writing". The reliability of the seven items was satisfactory (α = .79, in pre-test; α = .83, in post-test).

For STEM career interest, we adapted a measure used in Robnett and Leaper's study [58]. Each child was asked to indicate how true it is for them that "they want to become a scientist/engineer/science teacher/math teacher/computer programmer/astronaut/doctor) versus "I want to be something different". The seven items for this measure again reached satisfactory reliability (α = .79, in both pre-test and post-test). As a result, we averaged the items to form a composite. Finally, an open-ended question was also included in both the pre- and post-surveys asking the student to write down their first and second choice jobs that they would like to have in the future.

Science Examination Scores

Fifth-grade students typically sit for the state's assessments of academic readiness for various subjects (reading, mathematics, science, social studies) in the last month of the academic year. The science test includes questions from all units covered during the year, and addresses reasoning and content. We obtained the science scores for the students in both the Making group and the control group from the school district. We note that third- and fourth-graders are not tested in science at the state level.

DATA ANALYSIS AND RESULTS

Making Self-Efficacy, Interest and Identity

To address whether the classroom Making activities were related to students' sense of Making self-efficacy and interest in Making, and instilled a sense of identity as Makers, two analyses were done: A) a comparison of mean scores on the corresponding measures between students in the Making and control classrooms at the end of the academic year; and B) a comparison of means at the beginning of the academic year versus means at the end of the academic year for students in the Making classrooms. The SPSS statistical package was used for all analyses. No significant gender differences were found on any of our dependent variables. We were not able to look at any other differences that may arise from other demographic variables such as cultural background as there were not enough participants in each subgroup to make valid comparisons.

For the first analysis, an independent two-tailed t-test was run comparing the Making and control groups' post-test scores on Making self-efficacy, interest in Making and identification as a Maker (Table 2A). Results revealed that students in the Making classrooms reported significantly higher Making self-efficacy and interest in Making than students in the control classrooms ($p < .005$). Students in the Making classrooms also reported a somewhat greater

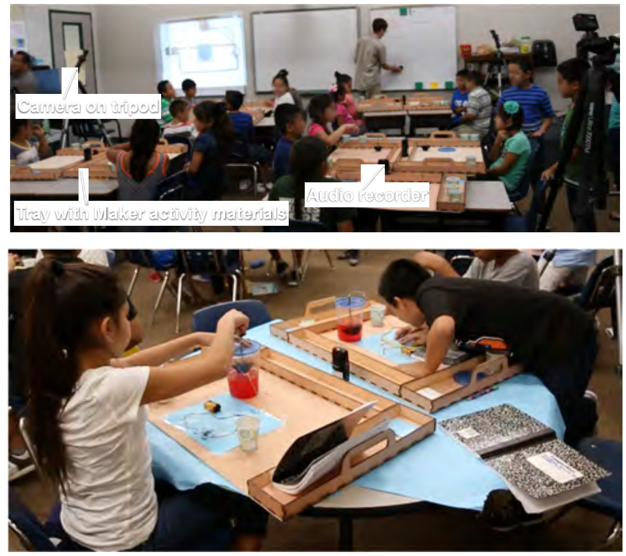

Figure 4. Students engaging in classroom Making activities

resonance with a Maker identity than students in control classrooms. However, this difference was not significant.

For the second analysis, a dependent two-tailed t-test was run on the Making group students' scores on Making self-efficacy, interest in Making, and identification as a Maker at pre- and post-test (Table 2B). No significant differences were found for any of the three variables. However, the means were relatively high at both time points for this group (all variables were measured on a 4-point scale; with higher numbers indicating more efficacy, interest, and identity). Note that the means here may not match the means in Table 2A given that only students with a complete pre- and post-test could be used in this analysis as it was a within-subject comparison. For the between-subject comparisons reported in Table 2A, all participants with post-test data could be included in the analysis.

Science Self-Efficacy, Interest and Career Paths

We conducted the same two types of analyses on the students' scores on science self-efficacy, interest in science, identification as possible scientists, and likelihood to have a STEM-related career. Overall, the results for these variables were more robust, suggesting that the intervention was effective particularly in boosting science than Making variables. For the first analysis (Table 3A), students in the Making classrooms reported significantly higher levels of science self-efficacy ($p < .005$), science interest ($p < .05$) and interest in STEM careers ($p < .05$) than students in the control class at the end of the academic year. The difference for possible self was marginally significant. For the second analysis, students in the Making classrooms reported significantly higher levels of science self-efficacy ($p < .005$), STEM possible self ($p < .005$), and STEM career interest ($p < .005$) at the end of the academic year relative to the beginning (Table 3B). The only difference that was not significant was for science interest, but these students reported relatively high levels of interest at the beginning of the year as well. Additionally, we found that the science variables were all significantly positively correlated with the Making variables (average r = .44).

Science Attitudes and Academic Performance

An independent two-tailed t-test was run on the scores of the fifth-graders in the Making group and the control group on their end-of-year state science examination. While students in the Making classes had somewhat higher test scores (M = 31.35, SD = 6.40) than students in the control classes (M = 29.75, SD = 6.21), this difference in scores was not statistically significant (p = .35).

Finally, we examined whether the Making and science variables were correlated with the students' scores on their end-of-year state science examination. Results from the tests revealed that Maker possible self (r = .35, p = .004) was significantly correlated with the examination scores. Maker self-efficacy (r = .23, p = .07) and Maker interest (r = .30, p = .07) trended with test scores but did not cross the significance threshold. Of the science variables, both science self-efficacy (r = .25, p = .04) and science interest (r = .25, p = .003) were significantly correlated with the examination scores. Neither STEM possible self (r = .18, p = .16) nor STEM career interest (r = -.01, p = .94), were strongly related to the examination scores.

Since it was still possible for our Making intervention to have increased examination scores via mediation effects of increased interest, self-efficacy and identification with science, we tested five mediation models using Hayes' [59] (model 4) PROCESS macro. For each model, science class type (Control class = 0; Making class = 1) was entered as the independent variable; examination scores were entered as the dependent variable; and a single science or Making variable was entered as the mediating variable. Bias-corrected confidence intervals for the effects in this model were computed based on 5,000 bootstrapped resamples. Results of this analysis revealed a significant indirect effect of science class type on test scores through science interest (b = 1.12, SE = .73, bias-corrected 95% CI = [.04, 3.05]) and science self-efficacy (b = .89, SE = .64 bias-corrected 95% CI = [.07, 2.89]). Maker self-efficacy, Maker possible self and Maker interest were not significant mediators.

Open-Ended Career Choices

We coded the students' responses to the open-ended question about desired career paths using the following process: 1) blank responses or responses that could not be understood were counted as unknowns and were removed from the dataset; 2) the responses were standardized such that phrases referring to the same jobs were coded with a single term (e.g., "cop" and "policeman" were both coded as 'policeman'); 3) the standardized responses were grouped into categories based on field (e.g., "doctor", "nurse", "surgeon", "dentist" were all grouped into the category 'medicine'); 4) we found a large number of responses referring to medicine-related jobs (notably doctor) and veterinarian. We removed these from the dataset as well, although they were STEM-related fields, as they seemed to relate more to a cultural meme rather than actual possible selves; and 5) the rest of the categories were coded as being either STEM-related or non-STEM-related. STEM-related categories were "scientist" (included jobs like scientist, biologist, geologist, etc.), "engineer"

Table 2. Results for Making Self-Efficacy, Maker Interest, and Maker Identity

A. Intervention VS Control			
	Maker Classrooms Post-Test Mean (SD)	Control Classrooms Post-Test Mean (SD)	Independent t-test
Making Self-Efficacy	3.27 (.83)	2.77 (1.08)	t(171) = 3.37, p = .001
Maker Interest	3.27 (.82)	2.85 (1.01)	t(172) = 2.99, p = .003
Maker Identity	3.26 (.64)	3.17 (.60)	t(174) = .38, p = .38
B. Intervention Pre Vs Intervention Post			
	Maker Classrooms Pre-Test Mean (SD)	Maker Classrooms Post-Test Mean (SD)	Dependent t-test
Making Self-Efficacy	3.13 (.86)	3.28 (.80)	t(93) = -1.39, p = .17
Maker Interest	3.46 (.72)	3.32 (.74)	t(93) = 1.46, p = .15
Maker Identity	3.31 (.42)	3.32 (.55)	t(93) = -.22, p = .83

Table 3. Results for Science self-efficacy, Interest, Identity, and Career Interest

A. Intervention VS Control			
	Maker Classrooms Post-Test Mean (SD)	**Control Classrooms Post-Test Mean (SD)**	**Independent t-test**
Science Self-Efficacy	3.31 (.79)	2.81 (.91)	t (172) = 3.80, p < .001
Science Interest	3.49 (.79)	3.13 (.99)	t(170) = 2.58, p = .011
STEM Possible Self Composite	3.10 (.72)	2.88 (.70)	T(173) = 1.91, p = .058
Interest in STEM Career Composite	2.39 (.78)	2.07 (.66)	t(172) = 2.72, p = .007
B. Intervention Pre Vs Intervention Post			
	Maker Classrooms Pre-Test Mean (SD)	Maker Classrooms Post-Test Mean (SD)	Dependent t-test
Science Self-Efficacy	3.01 (.85)	3.33 (.74)	t(93) = -.322, p = .002
Science Interest	3.49 (.81)	3.52 (.72)	t(91) = -.33, p = .74
STEM Possible Self Composite	2.84 (.74)	3.11 (.68)	t(94) = -3.11, p = .002
Interest in STEM Career Composite	2.09 (.79)	2.40 (.79)	t(95) = -3.91, p <.001

(included jobs of engineer, robotics engineer, inventor), and "technology" (that included computer programmer, game developer, etc.).

Table 4 shows the percentage of STEM-related careers relative to non-STEM careers for each of the Making group pre-survey, Making group post-survey, and the control group post-survey. As first career choice, only 4.82% of the students in the Making classes wanted a STEM-related job at the beginning of the year (A1). This rose to 19.54% at year end (A2). In comparison, only 2.22% of the students in the control group (B) expressed STEM-related jobs as first career choice even at year end. Second career choices followed a similar pattern. The Making group saw the percentage of students listing a STEM-related job as second choice rise from 13.40% at year onset to 19.10% at year end. The control group however had only 9.09% of students listing STEM-related jobs at year end as second choice. We note as well that although we did not count 'teacher' as a STEM profession, listings of "teacher" in the pre-survey became more specific in the post-survey with a number of the students listing "science teacher" or "math teacher".

DISCUSSION

Our work set out to investigate the influences on third-, fourth- and fifth-grade students of consistently integrating Making into the science school curriculum over a year. We were interested in the students' self-efficacy, sustained interest and self-identity as Makers and as individuals with STEM interests. For Making to be able to impact the child outside the 'sandbox' [20] of study settings, it needs to be able to affect such variables that require longer time to develop. We note that we cannot determine true causality of any of the variables in our study given the constraints of our research design.

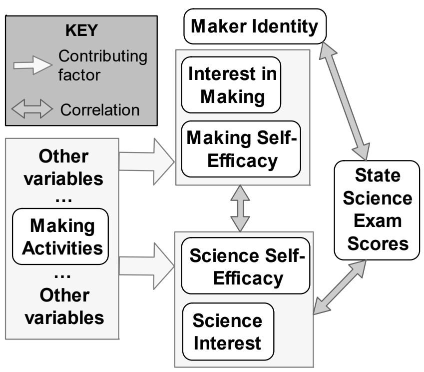

Figure 5. Results illustration

A summary illustration of our study results is shown in Figure 5. We saw that after a year of curriculum-integrated Making within the scope of the activities that we deployed, the students in the Making group reported greater self-efficacy and interest in Making than the control group at year end. The Making group also had greater self-efficacy in being able to do science, although they were not necessarily more interested in science. As for questions of identity, the students in the Making group did not necessarily feel completely inducted as Makers even after a year. It is highly encouraging though that the Making students' interest in STEM careers and sense of being possible STEM people were greater than the control group and increased over time. This is echoed by the change seen in the students' career choices on the open-ended survey question from the beginning to end of the year.

Table 4. Students' self-reported career choices (A1: Making group pre-survey; A2: Making group post-survey; B: Control group post-survey)

	A1	A2	B
Total Responses	117	115	61
Career Choice 1			
Unknowns	4	8	4
Medicine/Veterinarian	30	20	12
Total Responses Included	83	87	45
STEM careers	4	17	1
	(4.82%)	(19.54%)	(2.22%)
Non-STEM careers	78	70	44
	(95.18%)	(80.46%)	(97.78%)
Career Choice 2			
Unknowns	9	6	4
Medicine/Veterinarian	11	20	13
Total Responses Included	97	89	44
STEM careers	13	17	4
	(13.40%)	(19.10%)	(9.09%)
Non-STEM careers	91	72	40
	(86.60%)	(80.90%)	(90.91%)

Science examination scores were correlated with the students' Maker identity, science self-efficacy and science interest. This suggests that confidence and interest in science are important for academic achievement in the subject. More interestingly, the greater a student's identification as a Maker, the better his or her academic science performance was.

To answer our research questions directly thus, our approach to the integration of Making into the school curriculum: i) contributed to changes in Making self-efficacy and interest, and trended toward a Maker identity; ii) contributed to changes in science variables on self-efficacy and identity. No effect was found on science interest, which was already high from the onset; iii) did not lead to significant differences in science examination scores, but the latter co-varied with the students' level of Maker identity, science self-efficacy and science interest; and iv) contributed to qualitative changes in the career choices of a number of students.

These findings highlight key points that we believe add to our knowledge of the potential of curriculum-integrated Making in schools. First, Making may not necessarily increase one's interest in the subject matter of the Making. We found that after our Making intervention, the students had greater confidence in their ability to do science, and thus could possibly see themselves as future scientists. However, they were not significantly more interested in science as a topic. Borrowing Blikstein's 'keychain syndrome' scenario [10], the children making keychains using digital fabrication would be more confident that they know about keychains, and could possibly even see themselves as future keychain makers, but they may not become more interested in the topic of keychains itself. We suggest three possible explanations for this: 1) engagement in Making may be an enabler of science interest, but not a determinant of it as it seems to be for self-efficacy; 2) the increase in self-efficacy may not have crossed a certain threshold needed to produce gains in interest. Lenox and Subich [60] described such a threshold effect for self-efficacy and vocational interests; or 3) our interest measure suffered from a ceiling effect since the pre-test scores were already high and the scale did not allow the students to rate much higher in the post-test.

The significant change in science identity however was also reflected in the career choices that the students listed. More students listed STEM-related jobs as their first career choice after our intervention. These students gained both interest and self-efficacy, i.e., the child is strongly interested in STEM and believes she is able to do that job. More students indicated STEM-related jobs as their second career choice as well at year end. Out of the 17 students, 9 indicated a STEM job for second career choice but not as first choice. These students may have gained self-efficacy, but not necessarily interest. For these students, Making may have expanded their ‘toolbox of skills’ and broadened their scope of possibilities in life, even though they may not change their career goals to becoming scientists or engineers.

And second, curriculum-integrated Making may not be a direct contributor to academic achievement, but function more in indirect ways. The higher science examination scores for the Making group were not significantly different from the scores of the control group. However, the scores were mediated by science self-efficacy and interest that were both correlated with Making variables, that we affected through our intervention. In the classroom thus, it appears that Making is a multi-step function that may contribute to STEM learning.

Limitations

We acknowledge that our study has several limitations that should be noted. First, we intervened for a week in every unit in the science curriculum. This amounted to a Making week every six weeks for the students in each class over the academic year. It is certainly possible that a continuous Making intervention may lead to amplified effects that we were not able to detect in our study. Second, no fixed guidelines exist currently as to how to integrate Making into an elementary school curriculum. We drew from an interdisciplinary group to design our Making kits and activities that made up the intervention. It is possible that implementation technicalities may have influenced results.

Third, the school ecosystem is very complex. It was not possible for us to account for all the potential confounding variables that may have influenced the students throughout the year, e.g., exposure to outside activities, teaching styles, etc. Although all students were from the same school and neighborhood, and the groups were likely comparable on many accounts, there are dynamics in student selection and classroom and school organization that affect students' ratings and performance. Nonetheless, the study provided important data that may hopefully help us to understand more about how Making may function in public school settings. Finally, although we intervened for only selected learning standards for each science unit in the curriculum, our analysis looked at the impact on overall science examination scores. In future analysis, we will isolate the examination script for questions relating only to the standards covered in our Making intervention.

CONCLUSION

We presented results from a year-long study with over 120 students from three grades in a public elementary school. We evaluated the influence of students engaging in a sustained manner with Making technology integrated with a public school curriculum on their self-efficacy, interest, and self-identity with respect to Making and STEM. Our study results showed that the greatest relationship is with science self-efficacy and identity. We also saw that our intervention approach of using Making as the tool for learning science may influence science examination scores through the students' science self-efficacy and identity. These results are important because children between ages 8 and 11 are beginning to develop their nascent self-identities by discovering what they may be good at. This efficacy and possible identity can support greater resiliency in the study of STEM subjects as they progress through school.

Our work provides a foundation for many other trajectories. For example, future investigations can look at students' interactions with other Making technologies beyond electronics, such as programming with microcontrollers. Our study focused on the third- to the fifth-grade in science. Further research may relate the approach to other K-12 grade levels and to other subjects like mathematics or the language arts. And finally, another potential direction may be to see if Making skills acquired in the course of classroom activity may impact their interest and use of Making beyond the classroom.

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REFERENCES

1. Dougherty, D., *The Maker Mindset*, in *Design, Make, Play: Growing the Next Generation of STEM Innovators*, M. Honey and D.E. Kanter, Editors. 2013, Routledge. p. 7-11.

2. Halverson, E.R. and K.M. Sheridan, *The Maker Movement in Education.* Harvard Educational Review, 2014. **84**(4): p. 495-504.
3. Meintjes, R. and H. Schelhowe. *Inclusive Interactives: the Transformative Potential of Making and Using Craft-Tech Social Objects Together in an After-School Centre*. in *Proceedings of the The 15th International Conference on Interaction Design and Children*. 2016. ACM.
4. Hudson, N., C. Alcock, and P.K. Chilana. *Understanding Newcomers to 3D Printing: Motivations, Workflows, and Barriers of Casual Makers*. in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.(To appear)*. 2016.
5. Lindtner, S., S. Bardzell, and J. Bardzell. *Reconstituting the utopian vision of making: HCI after technosolutionism*. in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. 2016. ACM.
6. Taylor, N., U. Hurley, and P. Connolly. *Making community: the wider role of makerspaces in public life*. in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. 2016. ACM.
7. Bull, G. and R. Berry, *Connected Classroom Classroom Engineering and Craft Technologies.* Learning and Leading with Technology, 2011. **38**(5): p. 26.
8. Bull, G., et al., *An educational framework for digital manufacturing in schools.* 3D Printing and Additive Manufacturing, 2015. **2**(2): p. 42-49.
9. Blikstein, P. and D. Krannich. *The makers' movement and FabLabs in education: experiences, technologies, and research*. in *Proceedings of the 12th International Conference on Interaction Design and Children*. 2013. ACM.
10. Blikstein, P., *Digital Fabrication and 'Making'in Education: The Democratization of Invention.* FabLabs: Of Machines, Makers and Inventors, 2013: p. 1-21.
11. Nemorin, S., *A critical perspective on 'Making'in school: The implementation of 3D printing in high-school settings*, in *FabLearn Conference*. 2015, Stanford University: Palo Alto, CA.
12. Papavlasopoulou, S., M.N. Giannakos, and L. Jaccheri, *Empirical Studies on the Maker Movement, a Promising Approach to Learning: A Literature Review.* Entertainment Computing, 2016.
13. Flores, C. and T. Springer. *Authentic Learning and Assessment in the Self-Directed Environment of a Middle School Maker Space*. in *Workshop on Digital Fabrication in Education at the 12th International Conference on Interaction Design and Children (IDC)*. 2013. Bremen, Germany.
14. Posch, I. and G. Fitzpatrick. *First steps in the FabLab: experiences engaging children*. in *Proceedings of the 24th Australian Computer-Human Interaction Conference*. 2012. ACM.
15. Sheridan, K., et al., *Learning in the making: A comparative case study of three makerspaces.* Harvard Educational Review, 2014. **84**(4): p. 505-531.
16. Worsley, M., *Making with Understanding: Research on Studies from a Constructionist Learning Environment*, in *Graduate School of Education*. 2014, Stanford University.
17. Nemorin, S. and N. Selwyn, *Making the best of it? Exploring the realities of 3D printing in school.* Research Papers in Education, 2016: p. 1-18.
18. Hamner, E., et al. *Robot Diaries: Broadening Participation in the Computer Science Pipeline through Social Technical Exploration*. in *AAAI Spring Symposium: Using AI to Motivate Greater Participation in Computer Science*. 2008.
19. Hamner, E., T. Lauwers, and D. Bernstein. *The Debugging Task: Evaluating a Robotics Design Workshop*. in *AAAI Spring Symposium: Educational Robotics and Beyond*. 2010.
20. Jenkins, T. and I. Bogost. *Escaping the Sandbox: Making and Its Future*. in *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*. 2015. ACM.
21. Halverson, E.R. and K. Sheridan, *The Maker Movement in Education.* Harvard Educational Review, 2014. **84**(4): p. 495-504.
22. Martin, L. and C. Dixon. *Youth Conceptions of Making and the Maker Movement*. in *12th International Conference on Interaction Design and Children (IDC)*. 2013. ACM.
23. New York Hall of Science, *Making Meaning (M2)*. 2013: New York: New York Hall of Science.
24. Kuznetsov, S. and E. Paulos. *Rise of the expert amateur: DIY projects, communities, and cultures*. in *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*. 2010. ACM.
25. Tanenbaum, J., et al. *Democratizing Technology: Pleasure, Utility and Expressiveness in DIY and Maker Practice*. in *CHI '13*. 2013. Paris, France: ACM.
26. Katterfeldt, E.-S., N. Dittert, and H. Schelhowe, *Designing digital fabrication learning environments for Bildung: Implications from ten years of physical computing workshops.* International Journal of Child-Computer Interaction, 2015.
27. Qiu, K., et al. *A curriculum for teaching computer science through computational textiles*. in *Proceedings of the 12th International Conference on Interaction Design and Children*. 2013. ACM.
28. Ornelas, N.O., G. Calderon, and P. Blikstein. *Makers in Residence Mexico: Creating the Conditions for Invention*. in *Short paper at FabLearn Europe: Digital Fabrication in Education Conference*. 2014.
29. Chu, S.L., et al., *Making the Maker: A Means-to-an-Ends approach to nurturing the Maker mindset in elementary-aged children.* International Journal of Child-Computer Interaction, 2015.
30. Alexander, C., et al. *Piloting innovative learning experiences: Measuring outcomes of digital fabrication activities across five classes*. in *Proceedings of Society for Information Technology & Teacher Education International Conference 2013*. 2013.
31. Holbert, N., *Leveraging cultural values and "ways of knowing" to increase diversity in maker activities.* International Journal of Child-Computer Interaction, 2016.
32. Bandura, A., *Self-efficacy: toward a unifying theory of behavioral change.* Psychological review, 1977. **84**(2): p. 191.
33. Bandura, A., *Self-efficacy mechanism in human agency.* American psychologist, 1982. **37**(2): p. 122.
34. Bandura, A., N.E. Adams, and J. Beyer, *Cognitive processes mediating behavioral change.* Journal of personality and social psychology, 1977. **35**(3): p. 125.
35. Bandura, A. and D.H. Schunk, *Cultivating competence, self-efficacy, and intrinsic interest through proximal self-*

motivation. Journal of personality and social psychology, 1981. **41**(3): p. 586.
36. Bandura, A., et al., *Self-efficacy beliefs as shapers of children's aspirations and career trajectories.* Child development, 2001. **72**(1): p. 187-206.
37. Wang, X., *Why students choose STEM majors motivation, high school learning, and postsecondary context of support.* American Educational Research Journal, 2013: p. 0002831213488622.
38. AAUW, *Shortchanging Girls, Shortchanging America*. 1990, American Association of University Women: Washington DC.
39. Zimmer, L. and S. Bennett. *Gender Differences on the California Statewide Assessment of Attitudes and Achievement in Science*. in *Annual Meeting of the American Educational Research Association*. 1987.
40. Piaget, J., *The language and thought of the child (1923)*. 1973, New York: World.
41. Osborne, J.W., *Identification with Academics and Academic Success among Community College Students.* Community College Review, 1997. **25**(1): p. 59-67.
42. Festinger, L., *A theory of cognitive dissonance*. Vol. 2. 1962: Stanford university press.
43. Carver, C.S. and M.F. Scheier, *Control theory: A useful conceptual framework for personality–social, clinical, and health psychology.* Psychological Bulletin, 1982. **92**(1): p. 111-135.
44. Higgins, E.T., *Self-discrepancy: a theory relating self and affect.* Psychological review, 1987. **94**(3): p. 319.
45. Swann, W.B., A. Stein-Seroussi, and R.B. Giesler, *Why people self-verify.* Journal of personality and social psychology, 1992. **62**(3): p. 392.
46. Setterlund, M.B. and P.M. Niedenthal, *" Who am I? Why am I here?" Self-esteem, self-clarity, and prototype matching.* Journal of personality and social psychology, 1993. **65**(4): p. 769.
47. Hannover, B. and U. Kessels, *Self-to-prototype matching as a strategy for making academic choices. Why high school students do not like math and science.* Learning and instruction, 2004. **14**(1): p. 51-67.
48. Beyers, R.N., *Nurturing creativity and innovation through FabKids: A case study.* Journal of Science Education and Technology, 2010. **19**(5): p. 447-455.
49. Chan, J., T. Pondicherry, and P. Blikstein. *LightUp: an augmented, learning platform for electronics*. in *Proceedings of the 12th International Conference on Interaction Design and Children*. 2013. ACM.
50. Kafai, Y., D. Fields, and K. Searle, *Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools.* Harvard Educational Review, 2014. **84**(4): p. 532-556.
51. McKay, C. and K. Peppler. *MakerCart: a mobile fab lab for the classroom*. in *Position Paper at the Interaction Design for Children Conference (IDC)*. 2013.
52. Hughes, J., G. Gadanidis, and C. Yiu, *Digital Making in Elementary Mathematics Education.* Digital Experiences in Mathematics Education, 2016: p. 1-15.
53. Angello, G., et al. *Making as the New Colored Pencil: Translating Elementary Curricula into Maker Activities*. in *Proceedings of the The 15th International Conference on Interaction Design and Children*. 2016. ACM.
54. Harter, S., *Manual for the self-perception profile for children*. 1985: University of Denver.
55. The Maker Effect Foundation. *The Maker Mindset Assessment*. 2015 [cited 2015 July]; Available from: http://www.themakereffect.org/maker-research/.
56. Bandura, A., *Guide for constructing self-efficacy scales.* Self-efficacy beliefs of adolescents, 2006. **5**: p. 307-337.
57. Anderman, E.M., L.H. Anderman, and T. Griesinger, *The relation of present and possible academic selves during early adolescence to grade point average and achievement goals.* The Elementary School Journal, 1999: p. 3-17.
58. Robnett, R.D. and C. Leaper, *Friendship groups, personal motivation, and gender in relation to high school students' STEM career interest.* Journal of Research on Adolescence, 2013. **23**(4): p. 652-664.
59. Hayes, A.F., *PROCESS: A versatile computational tool for observed variable mediation, moderation, and conditional process modeling*. 2012: White Paper.
60. Lenox, R.A. and L.M. Subich, *The Relationship Between Self-Efficacy Beliefs and Inventoried Vocational Interests.* The Career Development Quarterly, 1994. **42**(4): p. 302-313.