IMPACTS OF INCLUSIVE MAKER PROGRAMMING ON STUDENTS' ENGINEERING KNOWLEDGE AND INTEREST

S. Gardner[1], A. Woods[1], L. Jackson[1], A. Riccio[2], W. Martin[2]

[1]SRI International (UNITED STATES)
[2]Education Development Center (UNITED STATES)

Abstract

Involving the hands-on production of physical or digital artifacts, maker programs are an engaging way for youth to pursue their personal interests while learning the engineering design process (EDP) [1], [2]. Although autistic youth often have deep interests related to science, technology, engineering, and math (STEM) [3] and autistic college students are drawn to STEM majors at higher rates than non-autistic peers [4], young autistic adults often have difficulty joining or remaining in the STEM workforce [5]. With the goal of creating maker programming to enable autistic youth to engage in the EDP with peers and to prepare autistic youth for future careers, a multidisciplinary team created the Inventing, Designing, and Engineering for All Students (IDEAS) Maker Program, now in its sixth year. IDEAS is run outside of instructional time in eight autism inclusion elementary, middle and high schools by special education and science teachers in those schools. The following paper describes the ways in which IDEAS supports autistic learners and describes findings from a STEM attitudes survey and EDP assessment that were administered to students in maker clubs at the beginning and end of the 2021-22 school year by the IDEAS research team. Results suggest that students who participated in maker clubs did not experience a pre- to posttest change in their STEM attitudes but did increase their knowledge and understanding of the EDP. We discuss limitations and considerations for teachers and schools interested in the maker club approach and researchers of STEM education and inclusion.

Keywords: Inclusion, autism, STEM, maker clubs, universal design for learning

1 INTRODUCTION

Maker programs within educational spaces engage students in iterative design and production, which can involve both physical and digital experiences and artifacts, and has value for developing a range of academic, social-emotional, and interpersonal abilities [6]. Making involves participants in the engineering design process (EDP) in which they learn to identify a problem, brainstorm ideas, plan, make, test, improve, and finalize maker projects (Fig. 1). These EDP skills are valued in both education and workforce settings [1], [2]. Experiences and benefits of engaging in the EDP with peers differ for autistic and neurotypical students. For non-autistic youth, programs that center established interests around social interactions with peers may spark interest in academic experiences and encourage students to explore how STEM disciplines may be relevant to their lives [7]. However, autistic youth are often already interested in academic topics such as STEM [3] as evidenced by the number of autistic people who major in STEM fields in higher education [4]. Joining or remaining in the STEM workforce can be more challenging for young autistic adults [5]. Opportunities to apply interests to real-word scenarios through hands-on practice such as the EDP [8] and experiences interacting productively with peers [9] can help prepare autistic youth for careers. To fill this gap, an inclusively designed maker program that enables neurodiverse youth to explore personal interests while developing highly valued STEM skills offers promise.

A multidisciplinary team of maker educators, experts in autism inclusion, engineers, educators from autism-inclusion middle schools, and researchers worked to create an inclusive maker program, the *Inventing, Designing, and Engineering for All Students (IDEAS) Maker Program*, now in its sixth year. IDEAS brought together experts in maker education, autism inclusion, engineering, co-design, and research to bring interest-driven maker clubs into autism-inclusion public schools in New York City. IDEAS is run outside of instructional time in eight autism-inclusion elementary, middle and high schools by special education and science teachers. Educators in these schools are trained in specialized teaching strategies for students with autism, including an evidence-based program that supports social-emotional development.

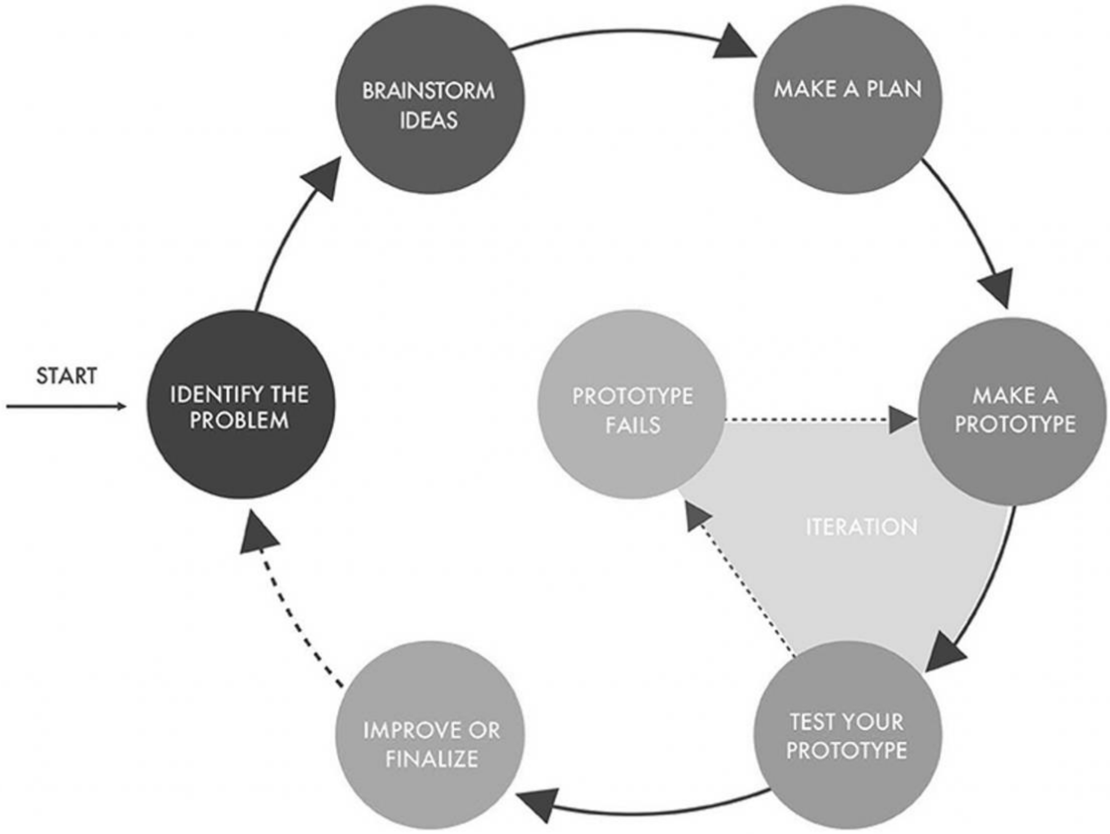

Figure 1. The engineering design process (EDP) model [10].

Research on the IDEAS Maker Program has demonstrated that it has had a positive impact for students overall, with increases in science and engineering self-efficacy, career interest, vicarious experience, science appreciation, and knowledge of the EDP [10]. In addition, teachers reported that students who often struggled with executive function and socializing were able to engage in and complete projects based on their interests and socialize with peers around the activities [11]. This paper presents findings from a STEM attitudes survey and EDP assessment the IDEAS research team administered to students in maker clubs at the beginning and end of the 2021-22 school year.

2 METHODOLOGY

2.1 Overview of evaluation

During the 2021-22 academic year, the IDEAS Maker Program was offered as an optional club run outside of instructional time for students at eight autism-inclusion elementary, middle and high schools. Students in these schools were informed about the maker program through recruitment flyers and recruitment events advertising the various clubs that the schools run. Parent/guardian consent forms describing the study were distributed to all maker program students. Any maker who was interested in participating and received parent consent/child assent was included in pre- and post- testing in the maker group. As a result of the COVID-19 pandemic, the research team shifted to all remote recruitment and data collection in 2020. Due to the logistical challenges of remote recruitment and assessment administration, the team found that it was only possible to administer pre- and post- maker club assessments to students in maker clubs; it was not possible to recruit non-makers remotely in any of the elementary, middle, and high school settings. The pre- and post-assessments consisted of a brief, online STEM attitudes survey and a two-question, spoken-response EDP assessment administered via Zoom. Maker club teachers shared the optional opportunity to take a survey with students and set up a laptop for students to take the assessment during maker club time should they choose to participate. A small incentive was provided to students who completed the pre- or post-assessment (e.g., a small gift such as a pencil or a $10 electronic gift card, depending on the teacher/school’s preferences).

2.2 Participants

A sample of 38 students (25 middle school and 13 high school) completed both the pre- and post-assessment. Participants were from five schools, but most attended one of three schools. The sample was about 60 percent male and 40 percent female. Participants identified as Asian (31.6%); Hispanic, Latino, or Spanish (26.3%); White (26.3%); Black or African American (10.5%); Middle Eastern (7.9%); American Indian, Native American, or Alaska Native (5.3%); or Other (21.1%). Participants could select more than one race or ethnicity (see Fig. 2). The study team initially enrolled 82 students at pre-assessment; however, due to COVID limitations, only 38 students were able to complete the post-assessment.

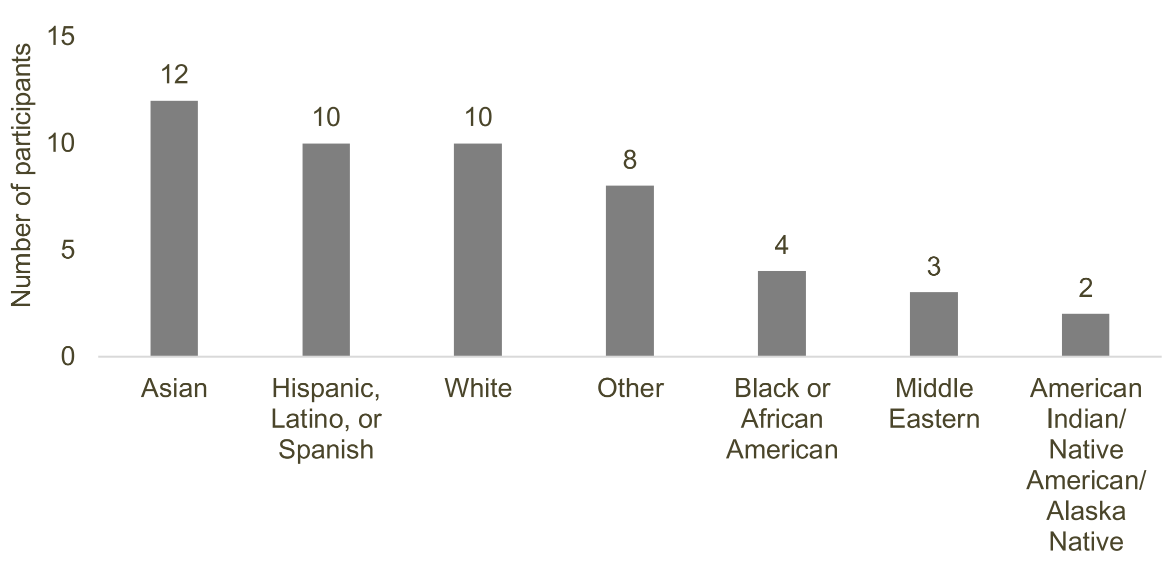

Figure 2. Student sample by race and ethnicity.

2.3 Instruments

The following instruments were administered to students remotely at pre- and post- testing.

2.3.1 STEM Attitudes Survey

The STEM attitudes survey was administered online through Qualtrics. The survey consisted of 24 items compiled from three existing surveys that demonstrated good internal consistency (IC) when implemented with middle school students [12], [13], [14]. These items were then separated into four subscales, described below. The full set of 24 items displayed good IC at both pretest (α=.85) and posttest (α=.98). We also investigated pre- to posttest differences on the four subscales. The *science appreciation* subscale (α_{pre}=.88; α_{fall}=.88) was measured by 9 items, including "Thinking about science is important to my life," "All people should learn lots of science in school," and "Scientists make our lives better." The *STEM career interest* subscale (α_{pre}=.57; α_{fall}=.84) was measured by 8 items, including "I am interested in working as an engineer," "I am interested in jobs that use technology," and "I like engineering activities." The *vicarious experience* subscale (α_{pre}=.55; α_{fall}=.68) was measured by 4 items, including "Seeing kids do better than me in science pushes me to do better," and "When I see how my science teacher solves a problem, I can picture myself solving the problem the same way." Lastly, the *STEM outcome expectation* subscale (α_{pre}=.66; α_{fall}=.76) was measured by 4 items, including "If I learn a lot about technology, I will be able to do lots of different jobs," and "My parents would like it if I chose to be an engineer." For a full list of items and descriptive information, see Tab. 1.

2.3.2 Engineering Design Process (EDP) Assessment

The EDP assessment administered was an adapted version of the instrument developed and validated by Hsu et al. [15] to assess elementary students' EDP knowledge. Brief, audio-recorded interviews were conducted over Zoom with students who answered questions based on a picture of a student using a process to design a container for an egg drop contest (Fig. 3). Students were asked what they thought about the process shown and whether they would do it differently. Responses were then coded by researchers according to a three-point scale (0 = no evidence noted, 1 = evidence noted, and 2 = evidence noted and elaborated).

Table 1. Descriptive information for STEM attitudes survey subscales and items (N = 38).

	Pre-Test		Post-Test	
	α	Mean (SD)	α	Mean (SD)
Science appreciation (9 items)	0.83	4.10 (0.58)	0.88	3.96 (0.57)
Thinking about science is important to my life.		3.84 (0.97)		4.00 (0.81)
All people should learn lots of science in school.		4.18 (0.80)		3.97 (0.82)
Being good at science is important to get a good job.		3.84 (1.08)		3.61 (1.00)
Understanding science helps people make sense of today's world.		4.34 (0.75)		4.37 (0.71)
Scientists cause more good than bad in the world.		4.03 (0.91)		3.89 (0.83)
Scientists make our lives better.		4.18 (0.69)		4.00 (0.74)
Understanding science is helpful for solving problems.		4.37 (0.67)		3.97 (0.82)
What I know about science will be useful outside of school.		4.18 (0.61)		3.89 (0.73)
Learning science will make me a better thinker.		3.89 (0.73)		3.97 (0.75)
STEM career interest (7 items)	0.57	3.21 (0.37)	0.84	3.16 (0.54)
I would feel comfortable talking to engineers.		3.63 (0.79)		3.63 (0.85)
Select the sentence that fits you best: I love/like/don't care about/hate engineering.[1]		1.84 (0.44)		1.92 (0.43)
If I learn a lot about engineering, I will be able to do lots of different jobs.		4.24 (0.68)		4.34 (0.67)
My parents would like it if I choose to be an engineer.		3.82 (0.93)		3.79 (0.99)
I am interested in working as an engineer.		3.55 (0.92)		3.47 (0.92)
I like engineering activities.		4.26 (0.55)		4.08 (0.67)
I am interested in jobs that use technology		4.24 (0.85)		3.97 (0.88)
Vicarious experience (4 items)	0.54	3.38 (0.59)	0.68	3.38 (0.65)
Seeing kids do better than me in science pushes me to do better.		3.39 (1.17)		3.37 (1.00)
When I see how my science teacher solves a problem, I can picture myself solving the problem the same way.		3.76 (0.59)		3.45 (0.76)
When I see how another student solves a science problem, I can see myself solving the problem the same way.		3.29 (0.80)		3.42 (1.00)
Seeing scientists do well in science pushes me to do better.		3.37 (0.88)		3.26 (0.89)
STEM outcome expectation (4 items)	0.66	4.13 (0.55)	0.76	4.11 (0.64)
If I learn a lot about technology, I will be able to do lots of different jobs.		4.24 (0.63)		4.32 (0.74)
If I learn a lot about engineering, I will be able to do lots of different jobs.		4.24 (0.68)		4.34 (0.67)
My parents would like it if I choose to be an engineer.		3.82 (0.93)		3.79 (0.99)
I am interested in jobs that use technology.		4.24 (0.85)		3.97 (0.88)
Full Scale (24 items)	0.82	3.49 (0.38)	0.98	3.59 (0.51)

[1]Item was reverse coded.

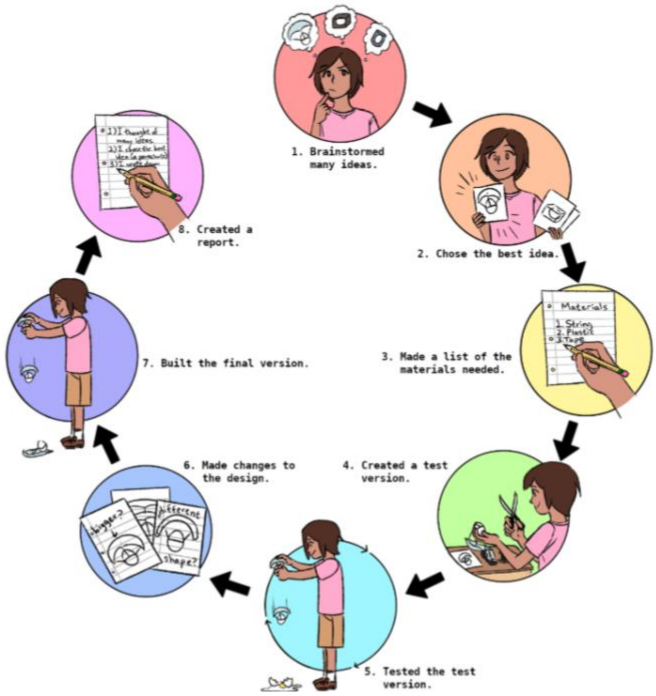

Figure 3. The figure presented to participants for the EDP assessment.

Prior versions of this assessment included an *Ask* domain (Asking about the details of the problem and constraints). Consistent with other studies (e.g., [16], [15]) few students endorsed *Ask* at either pre- or posttest, and there was virtually no growth across timepoints. Because *Ask* was neither directly addressed in the Makers program nor well represented on the EDP figure used for assessment, we removed this domain from further analysis and reporting, though results may be made available upon request.

3 RESULTS

We did not see significant growth on the STEM attitudes scale or subscales (Fig. 4). Although scores for the full scale were higher at posttest (M = 3.59, SD = 0.51) than pretest (M = 3.49, SD = 0.38), this difference was not statistically significant. None of the pre- to posttest differences on any STEM attitudes subscales were statistically significant. A ceiling effect does not appear to explain this pattern of findings.

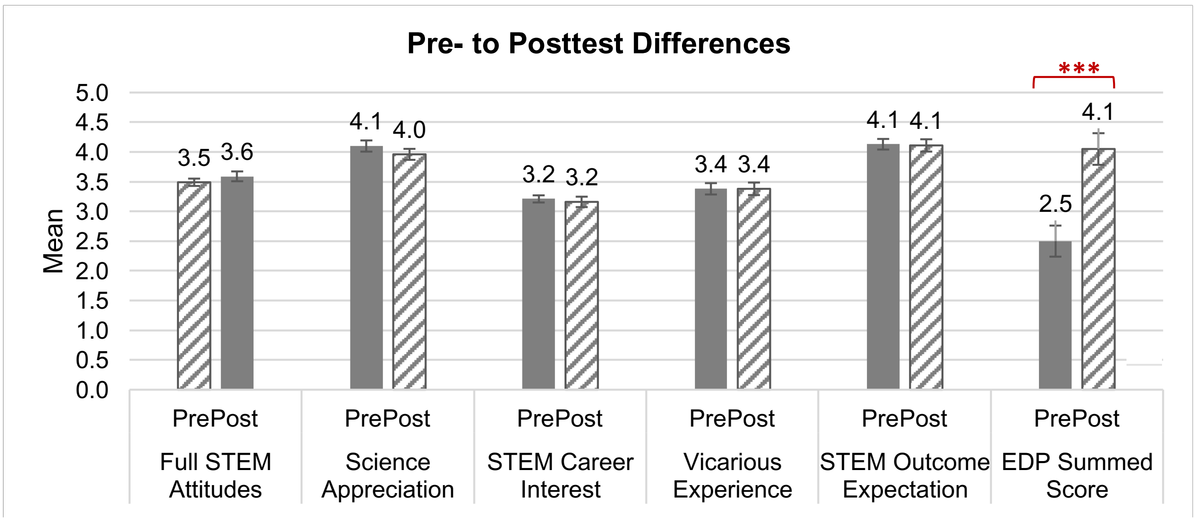

*Figure 4. Pre- to posttest differences on the STEM attitudes survey and the EDP assessment summed score. ***p < .001*

However, we did see a larger, statistically significant pretest (M = 2.50, SD = 1.61) to posttest (M = 4.05, SD = 1.64) gains on the total summed score for the EDP assessment. Pre- to posttest scores by item are displayed in Fig. 5. Across all items, we observed a trend of fewer students receiving a "0" (indicating that they did not mention the EDP element in their explanation) and more students receiving a "1" (briefly mentioned) or a "2" (mentioned and described more deeply). Pre- to posttest differences across individual items were statistically significant for 3 items: *Plan, Improve,* and *Test.* Significantly fewer students failed to endorse the *Plan* (29% fewer) or *Test* (26% fewer) aspects of the EDP at posttest. Conversely, significantly more students were able to deeply describe the *Plan* and *Improve* aspects of the EDP at posttest (13% more, each).

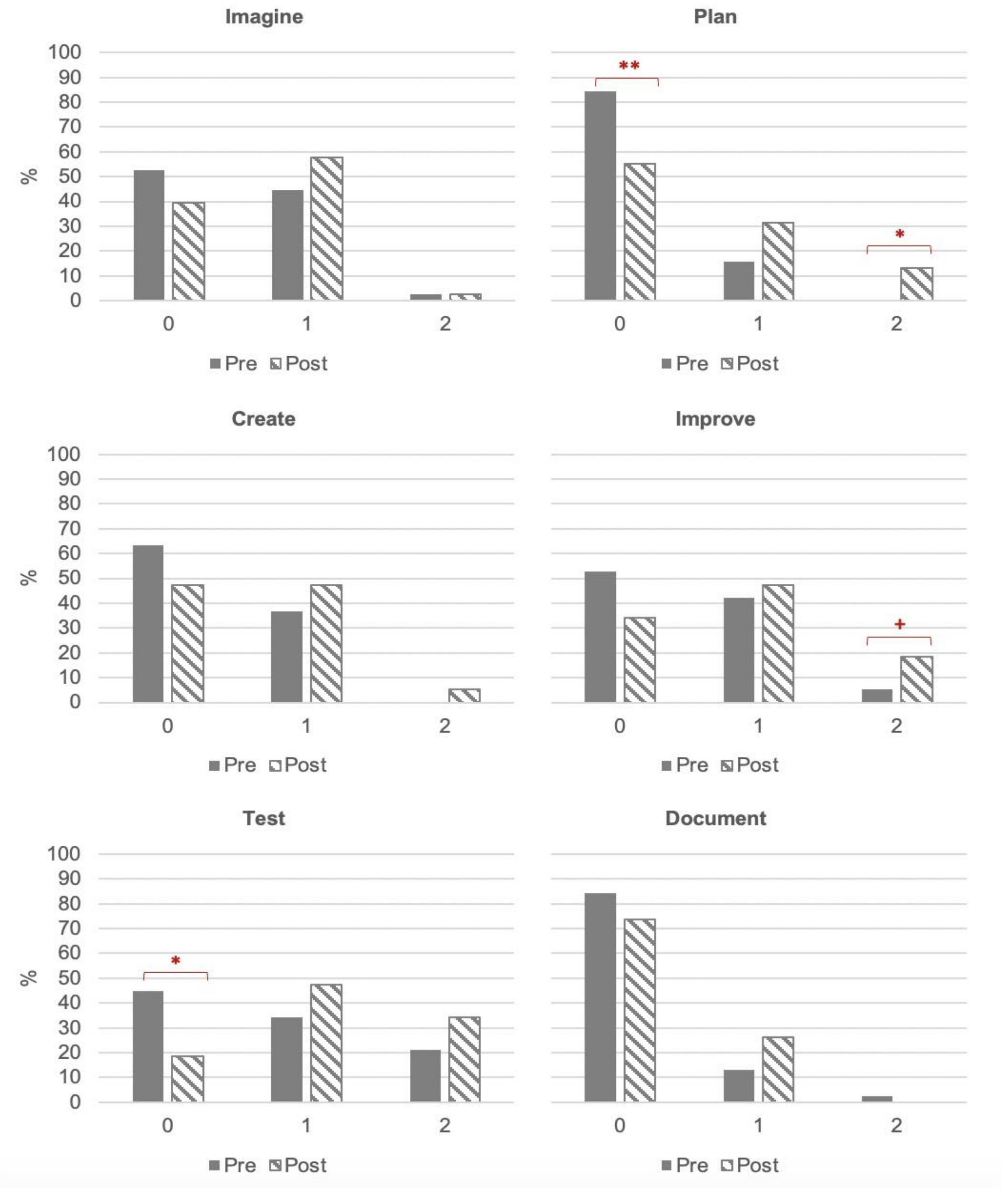

*Figure 5. Pretest and posttest differences in the proportions of students who did not endorse (0), partially endorsed (1), or fully endorsed (2) each EDP item (N = 38). **p < .01, *p < .05, +p < .10*

4 CONCLUSIONS

Although survey results showed consistent attitudes toward STEM before and after maker club participation, the EDP assessment showed a statistically significant pre to post gain, suggesting a positive impact on students' understanding of the EDP. This finding adds to a series of contributions from the IDEAS program. For example, in a separate study of the IDEAS program, teachers reported that students who often struggled with executive function and socializing were able to engage in and complete projects based on their interests and socialize with peers around the activities [11]. For educators and schools interested in maker clubs, these results indicate that they may offer students the opportunity for increased understanding of the EDP and socialization with peers. Limitations of the study include a reduced sample size given post-test attrition due to COVID-related scheduling and logistical constraints. Administering the survey and assessment by Zoom was challenging and time consuming to coordinate. We hope to conduct future data collection in person instead of virtually so we can improve participation rates.

Next, the study team plans to look at the results of the 2021-22 STEM attitudes survey and EDP assessment for differences across autistic and non-autistic students. Additionally, as the IDEAS program continues to scale further into high schools, the study team will be interested to see if and how high school students' outcomes and experiences in maker clubs compare to those of middle school students.

At the conclusion of this NSF-funded project, the study team plans to make the IDEAS maker club curriculum and materials available via open access to enable educators to invest in student interests, STEM exploration, and workforce development.

ACKNOWLEDGEMENTS

This work was made possible by a grant from the National Science Foundation ITEST #1850289. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

[1] L. Martin and C. Dixon, Eds., *Makers as Learners*, (New York: Routledge), 2016, pp. 183–195.

[2] B. Bevan, J. J. Ryoo, A. Vanderwerff, M. Petrich, and K. Wilkinson, "Making deeper learners: a tinkering learning dimensions framework," *Connect. Sci. Learn*. 7. 2018.

[3] M. South, S. Ozonoff, and W. M. McMahon, "Repetitive behavior profiles in Asperger syndrome and high-functioning autism," *J. Autism Dev. Disord*. vol. 35, pp. 145–158, 2015, doi: 10.1007/s10803-004-1992-8

[4] X. Wei, J. W. Yu, P. Shattuck, M. McCracken, and J. Blackorby, "Science, technology, engineering, and mathematics (STEM) participation among college students with an autism spectrum disorder," *J. Autism Dev. Disord*, vol. 43, pp. 1539–1546, 2013, Doi: 10.1007/s10803-012-1700-z

[5] P. T. Shattuck, S. C. Narendorf, B. Cooper, P. R. Sterzing, M. Wagner, and J. L. Taylor, "Postsecondary education and employment among youth with an autism spectrum disorder," *Pediatrics*, vol. 129, pp.1042-1049, 2012.

[6] E . Halverson and K. Peppler, Eds., *Maker Movement and Learning, in International Handbook of the Learning Sciences*, (New York; London: Routledge, Taylor & Francis Group), 2018, pp. 308–317.

[7] M. Ito, K. Gutiérrez, S. Livingstone, W. Penuel, J. Rhodes, and K. Salen, "Connected Learning: An Agenda for Research and Design," *Digital Media and Learning Research Hub*, 2013.

[8] A. Klin, J. H. Danovitch, A. B. Merz, and F. R. Volkmar, "Circumscribed interests in higher functioning individuals with autism spectrum disorders: an exploratory study," *Res. Prac. Pers. Severe Disabil*, vol. 32, pp. 89–100, 2007, doi: 10.2511/rpsd.32.2.89

[9] P. Wolfberg, M. DeWitt, G. S. Young, and T. Nguyen, "Integrated play groups: promoting symbolic play and social engagement with typical peers in children with ASD across settings" *J. Autism Dev. Disord*, vol. 45, pp. 830–845, 2015, doi: 10.1007/s10803-014-2245-0

[10] W. B. Martin, J. Yu, X. Wei, R. Vidiksis, K. K. Patten, and A. Riccio, “Promoting Science, Technology, and Engineering Self-Efficacy and Knowledge for All With an Autism Inclusion Maker Program,” *Front. Educ.* vol. 5, pp. 75, 2020, doi: 10.3389/feduc.2020.00075

[11] Y. L. Chen, K, Murthi, W. Martin, R. Vidiksis, A. Riccio, and K. Patten, “Experiences of students, teachers, and parents participating in an inclusive, school-based informal engineering education program,” *J. Autism Dev. Disord*, pp.1-12, 2021.

[12] J. A. Chen and E. L. Usher, “Profiles of the sources of science self-efficacy” *Learning and individual differences*, vol. 24, pp. 11-21, 2013.

[13] M. E. Bathgate, C. D. Schunn, and R. Correnti, "Children's motivation toward science across contexts, manner of interaction, and topic" *Science Education,* vol. 98, no. 2, pp. 189-215, 2014.

[14] M. W. Kier, M. R. Blanchard, J. W. Osborne, and J. L. Albert, "The development of the STEM career interest survey (STEM-CIS)" *Research in Science Education*, vol. 44, no. 3, pp. 461-481, 2014.

[15] M.C. Hsu, M. E. Cardella, and S. Purze, “Elementary students’ engineering design process knowledge: Instrument development and pilot test” In *2012 ASEE Annual Conference & Exposition* (pp. 25-512).

[16] M. E. Cardella, M. Hsu, and G.D. Ricco, “Analysis of design process knowledge task responses: Statistical approaches to uncover patterns (research)” in *121st ASEE Annual Conference & Exposition, 2014.*