Building engineering interest and resilience through maker programming in autism-inclusion schools

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Abstract

Maker programs, which involve hands-on production of physical or digital artifacts, are an engaging way to have youth pursue their personal interests as they learn the engineering design process (EDP) [1], [2]. Autistic youth often have deep interests related to STEM [3] and autistic college students are drawn to majors in STEM fields at higher rates than the general population [4]. However, 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. IDEAS brings 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. The following paper describes the ways in which IDEAS supports autistic learners in both in-person and online formats, and how IDEAS teachers responded to adversity by redesigning the curriculum for remote learning, editing materials to best suit their students in a remote environment, finding opportunities for students to socialize and share their maker projects online in unique ways, and ultimately providing an enriching and unique experience for students during Maker Club.

Introduction

The Maker Movement is a recent phenomenon, particularly within educational spaces, which recognizes that engaging in iterative design and production can involve both physical and digital experiences and artifacts and has value for developing a range of academic, social-emotional, and interpersonal abilities [6]. Our understanding of the value of making is influenced by foundational learning theories such as constructionism [7] which argues that learners construct new knowledge by building on what they already know through participation in active, open-ended challenges, and hands-on projects rather than didactic lectures or structured, closed-ended lessons. In addition to being open-ended and hands-on, 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. These EDP skills are valued in formal and informal education as well as workforce settings [1], [2].

For nonautistic youth, programs that harness established interests centered around social connections and peer culture may inspire them to delve into more academically-oriented experiences, explore their identity and see how disciplines such as science, technology, engineering, and math (STEM) may be relevant to their lives [8]. However, autistic youth often already have deep interests related to academic topics, including STEM fields [3]. In fact, autistic people who enter higher education are drawn to majors in STEM fields at higher rates than the general population [4]. To prepare autistic youth for careers, they can benefit from experiences that help them translate their interests into real-world applications through engaging in practices such as the EDP [9] and experiences that help them interact productively with peers [10]. Inclusive interest-driven maker programming, therefore, would seem a promising method...
for enabling a wide range of neurodiverse youth to pursue their personal interests while also gaining STEM skills that are valued in higher education and the workforce.

With this premise in mind, 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 to bring interest-driven maker clubs into autism-inclusion public schools in New York City. IDEAS has been hosted by eight total autism inclusion elementary, middle and high schools outside of instructional time by special education and science teachers in those schools. Research on the IDEAS Maker Program has demonstrated that it 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 [11]. 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 [12].

Along with these positive student outcomes, our team’s experience continuing the IDEAS Maker Program during the COVID-19 pandemic demonstrated how hosting a maker program can lead to positive teacher outcomes as well. When schools switched to remote learning in March of 2020, our co-design team demonstrated resilience in the face of this challenge. Over the summer, the team created materials and procedures to host the maker club virtually and conduct professional development on the revised club. Over the 2020-21 academic year, the team continued to improve the program, editing curriculum materials to best suit students in a remote environment, and finding opportunities for students to socialize and share their Maker projects online. By applying their maker mindset, our team was able to provide enriching programming to young people despite the difficulties this year presented. In addition, the virtual program and professional development materials that we created can now be shared more broadly than before, making this program more sustainable in the long run. To better suit different types of learners and to make the program more adaptable to settings without access to a 3D printer, the IDEAS team is creating new curriculum materials and teacher resources which focus on hand-built construction and materials exploration to be made publicly available by 2023. This paper presents findings from the past two years of this six-year research practice partnership in which the IDEAS Maker Program Curriculum was adapted, tested, iterated, finalized, and scaled for use within an inclusion setting specifically designed for autistic students to learn alongside nonautistic peers.

**Methods**

Adapting the IDEAS Maker Program

In the wake of a complete transition to remote learning in New York City due to COVID-19 for all after school/informal programming and to teacher professional development (PD) offerings, the IDEAS program underwent a significant shift during its fifth year of implementation. The IDEAS research and programming team, in collaboration with teachers, created remote-learning friendly curriculum materials, materials for virtual teacher PD, and a
process for conducting research and collecting data on program outcomes in a virtual environment.

To create an IDEAS Maker Program curriculum which was suitable for remote instruction, our co-design team developed a comprehensive slideshow for in-classroom use containing all IDEAS Maker Program activities from our existing curriculum, diagrams of the EDP, photos of past projects, and prompts to keep students engaged. Slides were uploaded to a shared drive and teachers were encouraged to edit the slides to best suit their specific students’ needs. After resuming in-person instruction in 2021, these materials continued to have utility and were further enhanced by our teacher facilitators based on their needs and experiences in the classroom. These slides and the entire IDEAS curriculum guide, including additional activities designed specifically for elementary-level students and for schools without access to 3D printer technology, will be available open-access at the completion of our grant funding period.

Teacher Surveys 2021

*Feedback following virtual PD.* Teachers were surveyed after attending each of seven virtual PD sessions, held once per month from October-April 2021. Each PD session focused on 1-2 activities from the IDEAS curriculum and aimed to provide teachers with all the tools and teaching strategies needed to successfully facilitate each activity, paying particular attention to any adaptations needed to implement the sessions in a remote learning environment.

*Feedback following remote Maker Club sessions.* Teachers were also asked to complete a post-club survey after each maker club session they facilitated during the 2020-2021 school year. This survey was designed to assess the degree to which teachers felt their students improved skills related to the EDP, had an opportunity to socialize with others, and completed the maker club session goal. Questions also assessed whether teachers felt supported in their facilitation of the IDEAS curriculum and adequately prepared to lead the activity. Teachers were invited to complete a survey after each session. Results include responses from 13 teachers who completed a total of 77 individual surveys.

Teacher Surveys 2022

*Feedback after resuming in-person Maker Club.* Teachers were asked to complete a post-club survey after each maker club session they facilitated during the 2021-2022 school year after sites resumed in-person instruction. As of April 2022, a total of 55 individual surveys have been collected from ten teachers across six sites. This survey included the same set of questions as the 2020-21 school year survey and added additional open-ended prompts. Open-ended prompts included: 1) “Describe an example of how students engaged in parts of the Engineering Design Process” and 2) “Describe an example of how students pursued their interests through making”.

**Results**

Results from 2020-21 Teacher Feedback Surveys
When combining all feedback data from all virtual PD sessions in 2020-21, teachers overwhelmingly agreed that they felt prepared to teach the goal activity in their own clubs. Overall (n=78), 56.4% strongly agreed that they felt prepared, 23.1% agreed, 19.2% felt neutral, and 1.3% disagreed.

When teachers were asked if they felt they had all the support they needed to facilitate a maker club session in the post-facilitation teacher survey, 62.3% of teachers strongly agreed that they did while 36.4% agreed. Teachers also responded positively when asked if they felt prepared to teach their maker club session; 45.5% of respondents strongly agreed that they felt prepared, 48.1% of respondents agreed that they felt prepared, and 5.2% of respondents felt neutral when reflecting on their level of preparedness.

When asked if their students made social connections during maker club, 44.2 % of teachers strongly agreed and 37.7% of teachers agreed that social connections were made. Overall, 9.1% of teachers felt neutral about whether their students made social connections, 6.5% disagreed, and 2.6% strongly disagreed. When asked if they felt their students improved their understanding of the EDP after participating in a session of the maker club, the majority of teachers strongly agreed (31.2%) or agreed (49.4%) that students improved EDP skills. 14.3% of teachers were neutral and 3.9% of teachers disagreed that their students improved EDP skills after a particular maker club session.

Results from 2021-22 Teacher Feedback Surveys

When teachers were asked if they felt prepared to teach their maker club session in the post-facilitation teacher survey, 67.9% of teachers strongly agreed that they did while 28.6% agreed. When asked if their students made social connections during maker club, 42.9 % of teachers strongly agreed and 48.2% of teachers agreed that social connections were made. Overall, 7.1% of teachers felt neutral about whether their students made social connections, and 1.8% disagreed. When asked if they felt their students improved their Engineering Design Process (EDP) skills after participating in a session of the maker club, the majority of teachers strongly agreed (26.8%) or agreed (57.1%) that students improved EDP skills while 14.3% of teachers were neutral and 1.8% of teachers disagreed that their students improved EDP skills after a particular maker club session. Results reflect a similar pattern of success in the 2021-22 school year when compared to results collected after remote learning maker clubs sessions in 2020-21.

Collecting open-ended responses in our teacher surveys yielding valuable insight for the research team’s understanding of how students pursued their interests and connected with one another while participating in the IDEAS Maker Club. Table 1 includes examples of teacher testimonials when reflecting on their students’ experiences.

<table>
<thead>
<tr>
<th>Open-ended Prompt</th>
<th>Selected Teacher Responses</th>
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<tbody>
<tr>
<td>Students from different grades / classes were sitting together. Students were sharing materials and making an effort to know each</td>
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Table 1. Responses to open-ended survey prompts from 2021-22 teacher facilitators
<table>
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<tr>
<th>“Describe any notable socialization you saw during your maker club session today”</th>
<th>other's names if the person wasn't in your class. One student did not remember the directions and was able to ask another student for help.</th>
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</thead>
<tbody>
<tr>
<td>J (student) asked a question to [teacher] about how to log into TinkerCad. She prompted him to ask 3 tablemates before returning to her. A helped him, and E (both students) commented on it. J continued to ask for validation throughout the lesson. M was also listening to the conversation (although not evident from his body language) and gave him good and helpful feedback.</td>
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<tr>
<td>Some kids were showing the others how to make twisty animals with the pipe cleaners we had in our supply bin. Others helped with glue guns, washi tape designs. At the end they showed each other how they designed their journals.</td>
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<tr>
<td>This activity really allows for a lot of collaboration and socialization. Some kids understand circuits and were able to get theirs working quickly. Other kids struggled, so we invited kids to help each other until all the light bulbs were lit.</td>
<td></td>
</tr>
<tr>
<td>Kids helped each other so much w tinkercad. There are always kids who struggle with it and kids who excel right away. The kids who caught on fast (or who already have experience with tinkercad) really stepped up to help the other kids.</td>
<td></td>
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<tr>
<td>“Describe an example of how students engaged in parts of the Engineering Design Process during maker club today”</td>
<td>One student who is left-handed came up with an alternative solution to create a journal which opens in the opposite direction so it will be easier for him to write in.</td>
</tr>
<tr>
<td>Students iterated on their designs from the previous session. Some reflected in their journals by taking pictures of their designs.</td>
<td></td>
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<tr>
<td>When making playdough designs, kids talked about how they could adapt the design to print it with the 3-D printer either by turning it on its side or making it in pieces.</td>
<td></td>
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<tr>
<td>When students had an idea fail in execution, we talked about how to make a new strategy that they could test out next, and we discussed the positive role of “failing” in the creative process.</td>
<td></td>
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<tr>
<td>K has been working on a Tinkercad project for a friend of hers and she has been struggling to create the correct shapes for what she's doing. She iterated a couple of different things for the shape of a shell until she found one that she liked.</td>
<td></td>
</tr>
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</table>

**Conclusions**

These findings have implications for the design of other inclusion programs for autistic and neurotypical youth in both formal and informal settings [10], [13]. Making as a pedagogical
strategy may be beneficial for inclusion because its openness and flexibility allows for a diversity of entry points into learning and doing, and in particular can support in-depth pursuit of areas of interest [6]. Using student interests as topics of conversation for social groups or as examples in content learning can increase engagement. Additionally, creating products based on interests can help students see how their interests connect to the larger world, and help them gain skills that may lead them into higher education and career pathways. Teacher feedback has demonstrated that educators feel their students, both autistic and nonautistic, gain critical social skills and EDP skills after completing the IDEAS Maker Program, demonstrating its utility in teaching these transferable skills across a variety of age groups.

At the conclusion of this NSF-funded project, our team aims to share an updated version of the IDEAS Maker Club curriculum guide, virtual professional development resources, and teacher materials such as slides, materials lists, and video testimonials. These materials will be available open-access in order to enable educators to invest in student interests, STEM exploration, and workforce development. It is our hope that our research findings and teacher testimonials will encourage additional classrooms and school districts to include autistic youth in the development or Maker programming to encourage student growth using these more informal and non-traditional, hands-on learning experiences.

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References


