# An Investigation of Students' Experiences in a K-12 Invention Program (Evaluation)

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# An Investigation of Students' Experiences in a K-12 Invention Program

## Abstract

The InVenture Challenge is an innovation-driven experience for K-12 students that operates in partnership with an institute of higher education. Students across all grade levels and educational settings (e.g., regular, gifted, and AP classrooms in a variety of subject areas; after school programs) are eligible to participate. Generally, students work in small groups to develop an invention from problem-seeking to prototype over the course of multiple months. In the process, they present their ideas to others, solicit feedback, and iterate on their design multiple times. In the spring, students with the top inventions from their individual schools travel to Georgia Institute of Technology to pitch their inventions to judges and audience members in a statewide competition.

The goal of this research is to understand the experiences of teachers and students within the program and the ways they benefit from participating. Initial research efforts have focused primarily on teachers' experiences implementing the program. Through survey, focus group, and interview data collected over the past several years, teachers have also provided their perspectives about how the program has impacted their students. Across several academic years, teachers' survey data reflects a high level of agreement that participation has had a positive impact on their students' communication and teamwork skills, enthusiasm for learning about engineering and entrepreneurship, and knowledge of the engineering design process, how products are made, how to design a sales pitch, and how to start a business.

In this paper, we summarize several years of teacher data related to perceived impact on students and present our first pre-post student survey data. This student survey data will allow us to directly investigate students' experiences within the program and examine alignment with their teachers' perceptions of student impacts. Together, this research will provide a multi-faceted view of invention education's impacts on students.

## Introduction, Background, and Guiding Questions

Educational institutions at both K-12 and post-secondary levels have ramped up efforts to provide students with opportunities to invent, often within the context of activities that fall under the maker movement [1]. Such opportunities take myriad forms, including required class projects, optional after school clubs, and school and state level competitions. Students may invent alone or in groups, their choice of what to invent may be constrained or wide open, they may share their inventions with classmates and teachers only, or with industry professionals and a wider audience outside their schools. Their inventions may be a physical product, an online tool or website, or something else entirely. A formal invention-focused curriculum may or may not be used. Underlying these widely varying educational efforts is the assumption that *students benefit in some way by going through the experience of inventing*.

What evidence do we have that this assumption is correct? What types of benefits do invention-focused educational curricula and experiences confer to students? While there is a

general sense that students benefit from involvement in these types of experiences, the formal literature reflects a limited understanding of what specific benefits to students occur through participation in invention education, as well as a lack of reliable and validated measures of these outcomes. Limited empirical evidence, gathered through interviews with educators, suggests that students who engage in maker-centered education may experience gains in problem-solving, risk-taking, teamwork skills, self-efficacy, and sense of community; the authors of this work emphasize the need for educators and researchers in this area to "document and assess maker-centered learning and teaching…to support research that looks at maker experiences through a learning lens" [2]. Figuring out how students benefit from invention-focused education, and what aspects of the educational experience specifically confer these benefits, is a critical element of amassing the robust set of empirical evidence necessary to justify the use of instructional time to pursue such experiences [1].

This paper aims to bolster our understanding of what students experience, and what they gain, when they participate in a specific invention-focused program. Evidence on the nature of their experiences, and the extent to and manner in which they benefit from these experiences, is taken from both teachers' reports on students' experiences as well as students' own reports about their experiences.

The InVenture Challenge (IC) is a university-based outreach program that seeks to inspire the next generation of engineers and entrepreneurs through invention education curriculum and events. The IC was originally developed in 2013 as a high school-level competition piloted by two high school science teachers. The teachers were mentored by creators of the Georgia Tech (GT) InVenture Prize, an undergraduate invention competition with a live TV show airing on Georgia Public Broadcasting [3]. During the 2016-17 school year, 2500 K-12 students participated in the IC program, with 82 of the top teams ranging from 1st through 12th grade presenting their inventions at the state finals held at Georgia Tech.

IC is unique in that it is generally teacher-facilitated, teamwork-oriented, and flexible. Students are free to work on a project of their choosing, and teachers are free to implement InVenture lessons where they see fit, and they often collaborate with teachers in other disciplines to do so. Teachers have used InVenture curriculum in Gifted classes, after-school programs, AP science and math courses, and even English classes, because of the heavy communication requirements.

IC event offerings include teacher professional development workshops in the summer, virtual (online) interim pitch feedback for students in the winter, and the state finals competition in the spring. Schools often host local competitions to determine their top teams for state finals. At state finals, students come to campus to compete with their inventions and are judged by university faculty, industry professionals, government representatives, and members of the education community.

Our efforts investigating IC have been ongoing since Spring 2015. Teachers were the initial focus of these efforts; through online surveys, focus groups, and interviews with teachers, we have gained a detailed understanding of both teachers' perceptions of IC, as well as their perceptions of how their students experience and benefit from IC. Across three academic years of collecting this teacher data, teachers have consistently reported high levels of agreement that

their students make gains in multiple outcomes as a result of their IC participation. These outcomes include knowledge about engineering and entrepreneurship, presentation skills, teamwork, knowledge about specific invention-related content, exposure to and increased interest in engineering, entrepreneurship, and invention related career paths, confidence, and understanding how the process of science works, among others [4], [5].

This research aims to follow findings from the teacher data, and was designed to investigate students' experiences and outcomes. We sought to triangulate the findings from our teacher data with student-reported data. The research questions guiding the student research, which entailed pre and post surveys for the 2016-2017 academic year, are as follows:

1. What is the nature of students' experiences with participating in IC?
2. What do students report in terms of their standing on outcomes of interest (e.g., 21st century skills, self-efficacy) at the beginning and end of their experience in IC?

In the sections that follow, we will summarize the methodology and results on both the teacher data on student experiences, and the student data.

## Methods

### *Research Design*

This research employed a mixed-methods design, in which quantitative data were collected through online surveys and qualitative data were collected through one open-ended online survey item, as well as through focus groups and interviews.

### *Participants*

**IC Teachers:** In most cases, all active IC teachers were invited to participate in research activities. One exception to this is the Fall 2016 online survey, in which only new teachers to the program were invited to participate (in an effort to avoid over-surveying returning teachers). The Spring 2015 teacher survey respondents are evenly split between elementary and high school. For the Spring 2016 and Spring 2017 teacher surveys, approximately one half of respondents are elementary school teachers, one quarter of respondents are middle school teachers, and one quarter of respondents are high school teachers. Across the three surveys, respondents implemented IC primarily during the school day in a variety of subject areas, with less than half a dozen respondents each year implementing during an after school club or organization. Most elementary school implementations took place in gifted programs. For some interviews and focus groups, teachers were strategically sampled on the basis of having participated for multiple years, being new to the program, and/or teaching a specific grade level.

**IC Students:** A particular school district was selected as the first site for the student-focused research. All participating IC teachers in this district were contacted near the start of the 2016-2017 academic school year and invited to participate in the student-focused research. Teachers were used as the point of contact, as the research team did not have sufficient resources to

directly facilitate student data collection at a large number of potential sites. Three teachers expressed interest in participating, and in Fall 2016, each was sent a research packet containing parent permission forms, student assent forms, and pre survey forms. One of these three teachers returned a completed research packet with a set of 12 surveys and permission and assent forms. This high school teacher was subsequently sent a research packet containing the post survey during Spring 2017; a set of 6 completed post surveys were returned from this packet. Thus our sample of students is comprised of 12 students for the pre survey, and 6 students who completed both the pre and the post versions of the survey. These students participated in InVenture Challenge as part of their AP Physics class. A subset of these students presented their health-care focused project at the InVenture Challenge state finals.

*Data Sources*

**Teacher Data**: Online surveys were conducted with IC teachers, once at the start of each academic school year and again after the conclusion of the IC program in spring, since Spring 2015, for a total of five survey implementations between Spring 2015 and 2017. These surveys contained a variety of items and scales, including teacher demographics and teaching background details, program implementation details, self-efficacy for teaching engineering and entrepreneurship, motivation for participating in IC, and teacher perceptions of the program's impact on their students. Only the last set of items related to teachers' perceptions of student experiences is presented in this paper. Only data from the spring teacher surveys will be presented due to the focus of this paper on student outcomes. For a full reporting of teacher survey data, see [4], [5].

Researchers constructed these items based on a set of perceived student outcomes and experiences associated with IC; teachers were asked whether they thought participating in IC increased their students' standing on the outcome of interest. These items were not formally validated as they are not intended to represent a single underlying construct; rather, they are aimed at gauging teachers' perceptions of the extent to which IC participation provided their students a variety of potential benefits. Sample sizes for the three spring surveys range from 8 teachers in the Spring 2015 data set to 22 teachers in the Spring 2016 data set.

Additionally, during the spring IC state finals event in 2016 and 2017, focus groups and/or interviews were conducted with teachers. Across the various years, teachers were invited for focus groups and interviews on the basis of grade level (e.g., elementary grades and middle/high school grades) or on the basis of experience with IC (e.g., either new or veteran IC teachers). Teachers were asked to discuss their experiences with IC, their motivation for participating in IC, how IC participation had affected their teaching, the level of support for IC provided by their school administration, and other related teacher-focused outcomes. Teachers were also asked to discuss the ways in which they felt IC participation had impacted their students. These teacher perceptions of IC's student impacts across years will be summarized in the results section. For more complete results on the qualitative data, see [4], [5].

**Student Data:** To complement the teacher-focused research efforts carried out over the past several years of IC implementation, student-focused research was undertaken beginning in Fall

2016. This research effort consisted of a student survey, following a pre-post design, administered at the beginning of Fall 2016 and again at the end of Spring 2017.

The survey was based on a similar survey on science and math related values and attitudes, used by the authors in a separate study within a similar setting. The survey contained basic demographic items, 77 closed-ended attitude and value items with a four point Likert-type scale ranging from "Strongly Disagree" to "Strongly Agree", 12 closed-ended job interest items with a four point Likert-type scale ranging from "Not at all interested" to "Very interested", a single multiple-choice item on approaching a complex task, as well as a single open-ended item about what the student found to be the most interesting thing about participating in IC.

### *The Student Survey*

A student survey was developed and validated for the purpose of measuring change in specific 21st Century Skills and other non-cognitive student attributes as part of a separate research project. The survey was developed and validated with a middle-school population in 2013. The instrument consists of 59 Likert-type self-report items in which students are asked to describe their level of agreement. The response options range from "Strongly Disagree" (=1) to "Strongly Agree" (=4). Cronbach's alpha is a measure of the internal consistency of a construct. This statistic ranges from 0 to 1.00. An alpha of .80 or higher is considered to have achieved very good measurement reliability; an alpha of .65 is considered acceptable [6]. For the purpose of this paper, only the constructs presented in the table below are analyzed, each of which shows good reliability.

Table 1. Cronbach's Alphas for Each Construct Measured throughout the Student Survey

| Construct Category | Construct | Cronbach's alpha |
|---|---|---|
| Self-efficacy | Self-Efficacy in Academics | 0.88 |
| Interest | Mathematics Interest | 0.90 |
| | Science Interest | 0.88 |
| 21st Century Skills | Value STEM Integration | 0.82 |
| | Learning Orientation | 0.84 |
| | Creative Problem Solving | 0.78 |
| | Teamwork & Collaboration | 0.88 |
| | Creativity & Communication | 0.76 |
| | Metacognition | 0.82 |

### *Data Analysis*

Descriptive statistics for the teacher and student survey data were conducted. Qualitative data from teacher interviews and focus groups, as well as from the single open-ended item on the student survey, were analyzed using thematic analysis [7].

### **Results: Teacher Data**

Descriptive statistics on teacher perceptions of student outcomes data across the three spring surveys are provided in Table 2.

Table 2. Teacher survey data; items on teacher perceptions of student impacts

| Teacher Perceptions of IC Impact on Students - Item: | SP15 | | | SP16 | | | SP17 | | |
|---|---|---|---|---|---|---|---|---|---|
| | # teachers | Mean | SD | # teachers | Mean | SD | # teachers | Mean | SD |
| Participating in InVenture Challenge has increased my students' enthusiasm for learning about engineering. | 8 | 5.63 | 0.52 | 22 | 5.50 | 0.67 | 21 | 5.43 | 1.21 |
| Participating in InVenture Challenge has increased my students' enthusiasm for learning about entrepreneurship/innovation. | 8 | 5.50 | 0.53 | 22 | 5.41 | 0.67 | 21 | 5.38 | 0.97 |
| Participating in InVenture Challenge has increased my students' ability to clearly present their ideas to others. | 8 | 5.50 | 0.76 | 22 | 5.55 | 0.67 | 21 | 5.48 | 0.98 |
| Participating in InVenture Challenge has increased my students' ability to work effectively in teams. | 8 | 5.50 | 0.53 | 21 | 5.48 | 0.68 | 20 | 5.55 | 0.60 |
| Participating in InVenture Challenge has increased my students' knowledge of the engineering design process. | 8 | 5.50 | 0.53 | 22 | 5.55 | 0.51 | 21 | 5.62 | 0.92 |
| Participating in InVenture Challenge has increased my students' knowledge of how products are made. | 8 | 5.13 | 0.64 | 22 | 5.41 | 0.67 | 21 | 5.29 | 0.90 |
| Participating in InVenture Challenge has increased my students' knowledge of how to design an effective sales pitch. | 8 | 5.25 | 0.46 | 22 | 5.59 | 0.50 | 21 | 5.62 | 0.59 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Participating in InVenture Challenge has increased my students' understanding of how to start a business. | 8 | 3.75 | 1.39 | 22 | 5.05 | 0.95 | 21 | 4.33 | 1.43 |

* Responses provided on a six-point response scale, with 1 = "Strongly Disagree" and 6 = "Strongly Agree"

These data indicate that, across years, in terms of a variety of potential student outcomes, teachers consistently provided high levels of agreement that their students benefited from participating in IC. On a six point scale, the majority of mean responses to these items were above a 5.5. Only twice did teachers provide a mean response of less than 5.0; both of these were on the item related to students understanding how to start a business.

Analysis of the qualitative data sources (i.e., teacher interviews and focus groups) across the years reveals that teachers described a variety of ways in which IC participation had impacted their students. The following themes emerged from the data; in this section, these themes are explained and illustrative quotes are provided.

### *Exposure to and increased interest in engineering and entrepreneurship content and experiences*

Teachers valued the opportunity to inform their students about engineering and entrepreneurship, both for improving content knowledge and for increasing student understanding of potential career paths in these domains and promoting student interest in such career paths. Teachers discussed specific experiences related to identifying and understanding consumer needs and creating and marketing a product to satisfy these needs. As a result of participating in IC, students gained a variety of technical and business-related skills they likely would not have gained elsewhere, including how to build a website, how to build an app, how to write a business plan, how to make a movie, how to talk in front of people, how to pitch something, how to convince people to buy something.

*One of the best experiences for our students was interviewing. Surveying and interviewing people. They could see how a simple question about, "What do you think about my idea?" would lead to so many new ideas and "Oh! I could do this…" To really listen to somebody else and hear what they're saying and add to your product because of a conversation you had [Spring 2016]*

*I think an interest level. The girls especially, who say, "Wow, I didn't realize I could do this!" [Spring 2016]*

*I have a kid that's here today who had an idea, didn't know how to do it, and taught himself how to code an app. Definitely that was something that he may not have done outside of the competition. [Spring 2017]*

*At the end of the project when we were just doing final reflections, I had the kids write some things down that they learned. First of all, how to build a website. Not all of them used Google sites. A lot of them used different web-building platforms and it was pretty neat for them. How to build an app, a lot of them didn't know that, how to do it, how to write a business plan. It was just ... How to make a movie, like a real movie. It was some pretty interesting skills that they ... How to*

*talk in front of people, how to pitch something, how to convince people to buy something. That was good. That was very good. [Spring 2017]*

*Personal Growth/21st Century Skills*

Teachers observed improvement in students' confidence, teamwork, innovation, and presentation and communication skills. They also noted that IC empowered students to seek out knowledge and develop skills on their own, rather than relying on teachers as their primary information source. Because IC provides students with an opportunity to engage in something that differs from traditional classwork, it allows students who may not excel in traditional classwork an alternate avenue for success.

*I think self-confidence. I think they better understand…what they're really good at…you see some of your non-traditional kids shine in InVenture because of their creativity or quirkiness or they thought of something…They just leave with a good understanding of their own strengths and weaknesses and how to approach long term projects and deadlines in the future [Spring 2016]*

*…and the whole collaboration piece is huge. Because some groups, if they're not cohesive or if somebody's railroading the group, it dissolves pretty quickly so they learn how to deal with different personalities and learn how to work as a collaborative unit which I think is really important [Spring 2016]*

*This student in my chemistry class had a 72 as we were going through the semester. By the end of the semester, he had brought his grade up to a B and was so much more invested in class time because he found success with this. It's something that I think he had been a little intimidated. He was selected to be part of the STEM program, he knew he liked engineering and all that kind of stuff, but I think just high school, life in a big high school had been overwhelming to him, and I think he felt a little insecure, and having been able to be part of this…It made a difference in his entire life…he gained confidence. [Spring 2017]*

*Well, and it's not traditional classwork. If they struggle with traditional classwork but they're interested in this sort of thing, they can show it through that performance, the performance tasks instead of the taking a test or whatever. [Spring 2017]*

*That's the whole thing too I think with this that's huge is problem solving. Especially with honors classes, I've found that those students are afraid to do anything wrong, so they would rather not start than to do something wrong. With these, it's almost like, "Do it and do it wrong, and then fix it, and then do it wrong again, and fix it," and just keep going on and on. This gives them the opportunity to fail and grow from that. [Spring 2017]*

*I think one of the first things, especially if you do it in middle school, is that giving them the idea that teacher doesn't necessarily have the answer. That you are*

*responsible for finding the answer and defending your answer and justifying your answer, because teacher doesn't know… it's important for them to realize that they have the responsibility and the ability to go out and find the information that they need. That's a skill that is handy everywhere in high school and beyond, so I think that's a big learning goal of that. [Spring 2017]*

### *Understanding of Science*

Teachers noted that students' experiences in IC taught them about the process of science, including the role of iteration, working through adversity and failure, the interdisciplinary nature of science, and the need for practicing rather than memorizing.

*They saw that too, like I should have changed this and I should have changed this, and they get to see what errors have occurred and what they should have changed. Oh, I need to redo my prototype, so they get to see all of that. Not just think, oh, if I do it one time it's going to be correct, and that's the end. I'm going to get it right the first time and that's it. No, that's not the case, and they saw that process, and I was so glad that they saw that process. I think that InVenture Challenge helped them to see that. [Spring 2016]*

### *Real-world Relevance*

Teachers recognized that students' experiences in IC provided them an arena in which to apply the content they had learned in school, and also motivated students to learn additional content in order to accomplish the goals they had with respect to their IC projects. Imagining how projects like these would play out in the real world, and what successful execution of them in the real world would require, also provided insight into possible courses of study and career paths that students may not have considered prior to their IC experiences.

*What can you possibly do with this particular skill? Oh, well, I never thought about it like that. Maybe I can major in engineering, or maybe I can open up a small business to do this that and the other…So knowing that what type of classes will you have to take, don't you think you need to take business, as well, since you're learning this? They're like, oh, yeah, I guess I would need that class to see the relevance. [Spring 2016]*

*I think it's a real world, real life, situation and we need to involve them in what's going on in the real world. [Spring 2016]*

We will now turn to the data provided directly by students to investigate students' own experiences.

## Results: Student Data

### *Demographics*

Of the 12 students responding to the pre survey, 7 are girls, 4 are boys, and 1 did not provide a response. The subset of 6 students who responded to both the pre and post surveys is comprised of 2 girls and 4 boys. The pre survey respondents' ethnicity data is as follows: 1 African American student, 6 Asian students, 1 Hispanic/Latino student, 3 White students, and 1 student responding with 2 or more ethnicity categories. Among the post survey respondents, there are 3 Asian students, 1 Hispanic/Latino student, and 2 White students.

### *Attitudes & Values Scales*

Descriptive statistics on pre survey data for all 12 pre survey respondents are provided in Table 3.

Table 3. Descriptive statistics on attitudes & values scales, pre survey respondents

| Scale | # items | # students | mean | SD |
|---|---|---|---|---|
| Math Interest | 3 | 12 | 3.28 | 0.57 |
| Value STEM Integration | 7 | 12 | 3.17 | 0.39 |
| Science Interest | 7 | 12 | 3.36 | 0.42 |
| Self-Efficacy | 8 | 12 | 3.14 | 0.53 |
| Learning Orientation | 5 | 12 | 3.30 | 0.40 |
| Creative Problem Solving | 5 | 12 | 2.98 | 0.42 |
| Teamwork & Collaboration | 8 | 12 | 3.39 | 0.43 |
| Creativity & Communication | 5 | 12 | 3.15 | 0.49 |
| Metacognition | 11 | 12 | 2.77 | 0.37 |

* Responses provided on a four-point response scale, with 1 = "Strongly Disagree" and 4 = "Strongly Agree"

Descriptive statistics on both pre and post survey data for all students who responded to both the pre and the post survey are provided in Table 4. These data were collected using a matched design.

Table 4. Descriptive statistics on attitudes & values scales, pre and post survey respondents

| Scale | # items | Pre Survey Data | | | Post Survey Data | | |
|---|---|---|---|---|---|---|---|
| | | # students | mean | SD | # students | mean | SD |
| Math Interest | 3 | 6 | 3.56 | 0.50 | 6 | 3.50 | 0.55 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Value STEM Integration | 7 | 6 | 3.21 | 0.25 | 6 | 3.07 | 0.35 |
| Science Interest | 7 | 6 | 3.45 | 0.51 | 6 | 3.31 | 0.40 |
| Self-Efficacy | 8 | 6 | 3.27 | 0.53 | 6 | 3.13 | 0.33 |
| Learning Orientation | 5 | 6 | 3.33 | 0.37 | 6 | 3.43 | 0.56 |
| Creative Problem Solving | 5 | 6 | 2.93 | 0.41 | 6 | 2.87 | 0.41 |
| Teamwork & Collaboration | 8 | 6 | 3.21 | 0.39 | 6 | 3.35 | 0.46 |
| Creativity & Communication | 5 | 6 | 2.83 | 0.34 | 6 | 3.23 | 0.34 |
| Metacognition | 11 | 6 | 2.67 | 0.37 | 6 | 2.80 | 0.20 |

\* Responses provided on a four-point response scale, with 1 = "Strongly Disagree" and 4 = "Strongly Agree"

While the small sample size of students responding to both the pre and post surveys precludes statistical comparisons of the pre and post scores on each of the attitude and value scales, we can examine the trends to provide at least a preliminary general picture of whether and how students' standings on these constructs compare across the two time points. On average, students responded on the positive side of the response scale, with mean responses on all scales at both time points at or above 2.50, which represents the midpoint of the response scale. A comparison of the mean pre and mean post score on each scale suggests that on nearly all scales, the mean response changed very little across these time points. One scale presents an exception to this finding of minimal change: on the Creativity & Communication scale, the mean response at the post time point was 0.40 points higher than the pre time point, indicating considerable positive change in students' average standing on this construct over the course of their IC participation.

### *Job Interest Items*

Students were asked on both the pre and post surveys to report their level of interest in jobs in a variety of areas. Responses were provided on the following scale: 1 = "Not at all interested", 2 = "Only a little interested", 3 = "Fairly interested", and 4 = "Very interested". Descriptive statistics for students' interest ratings across all employment areas are provided in Table 5.

Table 5. Students' level of interest in jobs in a variety of employment areas, pre-survey

| Item | Pre Survey Data | | |
|---|---|---|---|
| | # students | mean | SD |
| Physics | 12 | 2.58 | 0.90 |
| Veterinary Work | 12 | 1.83 | 0.72 |

| | | | |
|---|---|---|---|
| Biology and Zoology | 12 | 2.83 | 0.84 |
| Environmental Work | 12 | 1.83 | 0.72 |
| Mathematics | 12 | 2.50 | 1.09 |
| Medicine | 12 | 3.17 | 1.27 |
| Earth Science | 12 | 2.00 | 1.04 |
| Computer Science | 12 | 2.58 | 1.08 |
| Medical Science | 12 | 3.42 | 1.00 |
| Chemistry | 12 | 3.08 | 0.90 |
| Energy | 12 | 2.17 | 0.94 |
| Engineering | 12 | 2.50 | 0.80 |

* Responses provided on a four-point response scale, with 1 = "Not at all interested" and 4 = "Very interested"

For all respondents to the pre survey, a level of interest below the scale's midpoint of 2.5 was reported for four of the twelve employment areas: Veterinary Work, Environmental Work, Earth Science, and Energy. Students' reported interest levels were at or above the scale's midpoint of 2.5 for the remaining eight employment areas. The three highest rated employment areas were Medical Science, Medicine, and Chemistry.

Descriptive statistics were also conducted on the job interest items for the six students who responded to both the pre and post surveys, allowing for an examination of trends in their responses across the school year; these data are reported in Table 6.

Table 6. Students' level of interest in jobs in a variety of employment areas, pre-survey & post-survey

| Item | Pre Survey Data | | | Post Survey Data | | |
|---|---|---|---|---|---|---|
| | # students | mean | SD | # students | mean | SD |
| Physics | 6 | 2.83 | 0.98 | 6 | 3.17 | 0.75 |
| Veterinary Work | 6 | 1.67 | 0.82 | 6 | 2.17 | 0.41 |
| Biology and Zoology | 6 | 2.83 | 0.75 | 6 | 2.67 | 0.82 |
| Environmental Work | 6 | 1.67 | 0.52 | 6 | 1.83 | 0.75 |
| Mathematics | 6 | 2.67 | 1.03 | 6 | 2.83 | 1.33 |
| Medicine | 6 | 2.83 | 1.33 | 6 | 3.00 | 1.10 |
| Earth Science | 6 | 1.50 | 0.55 | 6 | 1.50 | 0.55 |
| Computer Science | 6 | 2.83 | 0.98 | 6 | 2.67 | 0.82 |
| Medical Science | 6 | 3.67 | 0.82 | 6 | 3.50 | 0.84 |
| Chemistry | 6 | 3.00 | 0.89 | 6 | 3.50 | 0.84 |
| Energy | 6 | 2.50 | 1.05 | 6 | 2.33 | 1.21 |
| Engineering | 6 | 2.83 | 0.75 | 6 | 3.33 | 0.82 |

* Responses provided on a four-point response scale, with 1 = "Not at all interested" and 4 = "Very interested"

The pre survey responses on these items from both the full sample and the subsample of students responding to both surveys show a similar pattern. A comparison of the pre and post responses shows that the sets of jobs clustered near the bottom and near the top of the interest ratings remained mostly unchanged. For most employment areas, the change from pre to post was minimal, with a change smaller than 0.20 in one direction or the other for eight of the twelve employment areas. For the other four jobs, changes of 0.33 – 0.50 were observed, and these were all in the direction of an increase in interest level from the pre to the post survey; these employment areas are Physics, Veterinary Work, Chemistry, and Engineering. Even after the 0.50 increase in mean interest rating, Veterinary Work remained fairly low with a mean interest rating of 2.17. But for the other three, the post-survey interest rating was 3.0 or higher.

***Open-Ended Item Analysis***

Students were asked a single open-ended question on the survey: "What was the most interesting thing to you about participating in InVenture Challenge?". A thematic analysis of students' responses to this item (both pre and post) revealed five general themes; each of these will be described, and illustrative quotes provided, below.

<u>*Learn and apply new information*</u>

Students discussed the opportunity to learn new information, and experience new things, through participating in IC. Students also recognized that their IC projects required them to apply the information they had learned in order to design or create something new.

*InVenture gave me an opportunity to step out of my comfort zone and try something new…*

*My favorite part of the InVenture Challenge was learning new things with my friends and group members and putting that new knowledge to use.*

*I learned how to use new equipment…I was able to have new experiences…*

<u>*Solve problems and help others*</u>

Students valued working on projects that would both solve problems in the world around them and directly help other people.

*The most interesting thing about participating in the InVenture challenge is coming up with a new product that you feel could benefit the society around you…*

*It provides me with insight of the engineering process and allows me to experience creating and marketing a device that could possibly have important global implications, or in the very least, improve someone's life*

*The most interesting thing to me was doing the research/talking to different people and coming up with an idea that not only is able to help just people, but also the environment and uses our natural resources the best we can.*

*…to be able to apply knowledge that I have studied in order to create my own product and help other people around me…*

### Collaboration

Students both enjoyed working with others and experienced positive growth in their ability to work and communicate with others. They recognized the benefits of others' contributions to their projects.

*I was able to work with a big group and listen to each person's ideas. I loved how everyone had different ways of thinking and new, creative ideas from every person.*

*The InVenture Challenge enabled me to reevaluate my ability to effectively work on a team and improve my communication and abstract thinking skills.*

*…I learned the importance of teamwork.*

*The chance to be able to work with my friends to create something that will hopefully aid others in this world.*

### Freedom

Students discussed the freedom they felt in working on this project, comparing it to their work in other classes, where their assignments are typically more constrained than is the case with their work on IC. They also valued that little guidance was required, and they were not expected to "get it right" the first time. This openness and freedom to fail without major consequences are a hallmark of the InVenture Challenge and these quotes suggest that students recognize and appreciate this aspect of their experience with IC.

*The freedom of it; unlike other engineering projects or science projects I feel that InVenture allows for almost anything. Whatever you find valuable to the world you can create without blatant restrictions…I enjoy the ability to try something new and different without the expectation of getting it right or perfect the first time.*

*With the InVenture Challenge, our group is given an amount of leeway, freedom, and opportunity to be creative that exceeds that of typical classroom work, which provides a nice change of pace from what we are accustomed to.*

*The chance to participate and create something outside of the confines of school, and being able to try out different approaches and solutions to a problem without having past knowledge or some sort of guided help.*

<u>*Exposure to broader community/engineering*</u>

Students discussed a variety of broader impacts, including enjoying visiting GT and attending both the InVenture Challenge state finals event and the InVenture Prize final competition, being exposed to other students with similar interests, being impressed by the skills of other students, and experiencing a heightened interest in engineering.

*The experience of the InVenture event itself was also incredible.*

*...it helped me become more interested in engineering*

*While the process itself of creating our design was very rewarding and enlightening, being able to view the ideas of others and even attending the challenge itself was very interesting...seeing others with the same interest and intrigue in the world of engineering was...fascinating*

**Discussion**

Teacher survey data collected at the close of the IC program over three consecutive academic years provide consistent evidence that teachers believe IC participation is benefiting their students in a variety of positive ways. The majority of teachers agreed that IC participation had increased students' enthusiasm for learning about engineering, enthusiasm for learning about entrepreneurship, presentation skills, teamwork skills, knowledge of the engineering design process, knowledge of how products are made, and knowledge about designing a sales pitch. The question on IC participation increasing students' understanding of how to start a business garnered lower levels of agreement at all three time points. These consistently lower mean scores on the item related to students' understanding of how to start a business provide clear evidence that the IC program is conferring this benefit to students to a lesser extent than other benefits, at least from teachers' perspective. Taken together, these data provide strong evidence that teachers perceive a variety of benefits being enjoyed by their students as a result of participating in IC.

The teachers expressed their positive views in the interviews and focus groups, which support the survey findings. Teachers discussed the value of IC as a platform to provide their students instruction on engineering and entrepreneurship content; they also highlighted specific skills, such as building a website, building an app, and writing a business plan, that students gained through their experiences in IC. Teachers also observed students' personal growth in such areas as self-confidence, teamwork, and presentation skills as a result of IC participation. Other positive aspects of IC recognized by teachers include its illustration of both the process of science and the real-world use of content students are learning in their other classes. All three teacher data sources,

surveys, interviews, and focus groups, show that teachers view IC as a program that provides myriad benefits to their students.

Student data demonstrate students' relatively high standing on the attitudes measured on both the pre and post surveys. Movement from pre to post was minimal for eight of the nine scales. This suggests that students did not show notable change in either direction on the measured attitudes over the course of their IC participation. Of the eight scales showing this minimal change, the direction of this change was a decrease from pre to post on five scales (Math Interest, Value STEM Integration, Science Interest, Self-Efficacy, and Creative Problem Solving) and an increase from pre to post on three scales (Learning Orientation, Teamwork & Collaboration, and Metacognition). One exception to this general finding of minimal change is on the Creativity & Communication scale, on which students increased nearly ½ point. So this initial trend analysis on our small sample suggests that IC participation may be positively impacting students' creativity and communication.

Students provided their level of interest in a variety of job categories. Generally, the categories of Medical Science, Medicine, and Chemistry were rated most favorably while the categories of Veterinary Work, Environmental Work, Earth Science, and Energy were rated least favorably. When pre and post survey responses are compared, an interesting pattern emerges: there was minimal change for most jobs, but more sizeable changes were observed for four of the twelve jobs (Physics, Veterinary Work, Chemistry, and Engineering) and all were in the direction of an increase from pre to post. While the sample sizes do not allow for statistical comparison, these trends suggest that some movement in job interest for certain employment areas occurred across the school year, and when it did, it was in a positive direction. It should be noted that this movement could be associated with InVenture Challenge participation, a variety of unrelated factors, or some combination thereof. Nevertheless, these trends suggest a potentially fruitful avenue for future research.

Students were asked a single open-ended survey item about what they found to be the most interesting thing about participating in IC. Some of their responses aligned closely with the student benefits reported by teachers: learning and applying new information, enjoying collaboration with other students and improving their teamwork skills, and exposure to the GT community and the engineering field. They also recognized some benefits in addition to those outlined by teachers: solving unique problems that would help others, and having the freedom to work on their projects with few constraints and without feeling they had to get it right the first time.

**Conclusions**

Multiple years of teacher data suggests that teachers perceive a variety of benefits to students as a result of IC participation. Student survey data do not show much movement in the constructs measured. There are a variety of possible explanations for this. The data suggest a slight ceiling effect, in that students' standings on these constructs were relatively high in the pre survey, leaving little room for increases on the

post survey. Perhaps the outcomes we measured are not affected by IC participation, or the measures themselves did not adequately capture students' standings on, and possible movement on, these constructs. We must also acknowledge the limitations of the extremely small sample size, and also the fact that a single teacher guided all of the students in our sample through IC, leading to limited variability in their experiences and a lack of understanding about how students experience IC across a variety of classroom contexts, subject areas, and settings.

Nonetheless, stability in these constructs is a notable finding. And one construct, Creativity & Communication, did show a sizeable increase from the pre to the post survey. Additionally, increases of a non-trivial size in students' interest in several job categories occurred from the pre to the post survey, suggesting that IC may have engendered additional student interest in these potential career paths, including engineering. Of course, outside factors could also have contributed in part or fully to this finding.

Lastly, student responses on the open-ended survey item provide the strongest evidence for alignment with the teacher-reported perceived impacts on students. Students provide positive comments about IC providing them with opportunities to improve their collaboration and problem-solving skills, learn and apply new knowledge, help others, and enjoy an educational experience free from the constraints associated with most of their coursework.

**Future Work**

Future work should serve to provide a more detailed and thorough understanding of students' experiences with IC and similar invention-focused or maker-focused education programs. Additional student surveys with a larger sample size across a variety of IC settings would allow for a more robust investigation of potential changes in the constructs of interest over the course of students' IC experiences. Student interviews and/or focus groups would complement the survey efforts and provide additional insight into how individual students experience and benefit from IC participation.

**Acknowledgements**

# References

[1]     Halverson, E.R. and K.M. Sheridan, "The Maker Movement in Education,"
        *Harvard Educational Review,* vol. 84, no. 4, pp. 495 – 504, Winter 2014.

[2]     Agency by Design, "Maker-Centered Learning and the Development of Self:
        Preliminary Findings of the Agency by Design Project, Project Zero": Harvard
        Graduate School of Education, 2015.

[3]     The InVenture Prize, https://inventureprize.gatech.edu/, Accessed September 28,
        2015.

[4]     Moore, R., M. Alemdar, S.H. Newton, and A.N. Holcomb, "The K-12 InVenture
        Challenge: Inspiring Future STEM Innovators" *Proceedings of the American
        Society of Engineering Education annual conference, Columbus, OH,* June, 2017.

[5]     Moore, R.A., S.H. Newton, and A.D. Baskett, "The InVenture Challenge:
        Inspiring STEM learning through Invention and Entrepreneurship," *International
        Journal of Engineering Education,* vol. 33, no. 1(b), pp. 361 – 370, 2017.

[6]     A. Field, *Discovering Statistics using SPSS (Third ed.).* Sage Publications, 2009.

[7]     V.Braun and V. Clarke, "Using thematic analysis in psychology," *Quantitative
        Research in Psychology*, vol. 3, no. 2, pp. 77 – 101, 2006.