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The InVenture Challenge: Inspiring STEM Learning Through Invention and Entrepreneurship*

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The InVenture Challenge seeks to bring design, engineering, invention, and entrepreneurship to K-12 education by providing a framework, curriculum, and competition that can be used by teachers in different disciplines with support from Georgia Institute of Technology faculty and staff. Modeled after Georgia Tech's InVenture Prize, a 'Shark-Tank' style competition for Georgia Tech undergraduates that is televised throughout Georgia, the InVenture Challenge attempts to deliver the same authentic experience to younger participants by providing resources and mentoring to K-12 teachers to implement engineering, design, and entrepreneurship lessons. In this paper, we present the motivation for the InVenture Challenge, lesson plans, resources, teacher survey feedback, and teacher focus group themes from the third year of implementation. The teacher survey data is related to perceptions of the program, self-efficacy for teaching engineering and entrepreneurship, observed student outcomes, challenges experienced during implementation, and recommendations for implementation within different schools and classroom settings. In general, teachers perceive the InVenture Challenge as an engaging way to introduce students to engineering and find value in the connection to the Georgia Tech community.

Keywords: invention; engineering; entrepreneurship; design; K-12; informal learning

1. Introduction

Many studies have demonstrated the need for greater participation and increased diversity in science, technology, engineering, and mathematics (STEM) to sustain economic growth and meet global challenges [1]. The inclusion of engineering in the Next Generation Science Standards [2] combined with the 'maker' movement [3] has increased pressure on K-12 teachers to incorporate hands-on projects, iterative design, and engineering thinking into their classrooms. These demands have led to new pedagogical requirements and challenges with respect to professional development and assessment for engineering content [4]. Completing engineering design projects in science and math classrooms (not just in technology or engineering classes) allows students to apply content directly to real-world problems while meeting the new national standards. However, completing open-ended projects during limited instructional time with standardized testing constraints can be challenging [5].

The K-12 InVenture Challenge (IC) provides a structured, simplified approach for teachers to guide students through an open-ended design problem within a domain of the students' choosing. The IC was developed as a high school-level competition with materials created by high school science teachers in partnership with the creators of the Georgia Tech (GT) InVenture Prize, an undergraduate invention competition with a live TV show airing on Georgia Public Broadcasting [6]. During the 2015–16 school year, 1500 K-12 students participated in the InVenture Challenge, with each school's top teams presenting their inventions at GT. In tandem, the 2015 GT InVenture Prize attracted 500 undergraduate inventors with a live TV broadcast to 1500 studio audience members and 50,000 TV viewers, making it the largest collegiate invention competition in the US. Since piloting in 2012, K-12 InVenture Challenge participants have matriculated into GT and other universities, often pursuing entrepreneurial activities on campus. In fact, several Inventure Challenge participants, frequently girls and as young as 6th grade, are pursuing patenting opportunities.

It is not uncommon for teachers to have anxiety about teaching design, engineering, and technology, particularly at the elementary levels [7]. To support teachers with limited or no engineering background, several lessons have been provided to guide teachers and students through a design process with engineering and entrepreneurial thinking included in the framework. In addition, each lesson is aligned to several state standards for Georgia in multiple disciplines including science, math, language arts, and STEM.

2. Background

The original InVenture Challenge materials were authored for high school audiences by two high

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school teachers during a summer internship program with two Georgia Tech professors who were instrumental in developing the GT InVenture Prize. During the 2012–2013 school year, the InVenture Challenge was piloted at two metro Atlanta high schools. The pilot was expanded to 10 additional high schools during the 2013–2014 school year. After a few elementary school teachers expressed interest in participating, elementary schools were added to the program in 2014–2015 for a total of 26 participating schools (4 elementary), reaching over four hundred students of varying grade levels. The elementary teachers modified the high school lessons and created a set of lessons that are appropriate for grade school audiences, which they generously shared with Georgia Tech and the InVenture Challenge community. In the fourth year, the program included participation from over 40 elementary, middle, and high schools across Georgia, reaching over 1500 students.

InVenture Challenge works in harmony with science fairs, robotics clubs, and other sponsored invention competitions. Many science fairs have recently expanded to include engineering projects, including the White House Science Fair [8] and the Intel International Science and Engineering Fair [9]. As such, IC projects are often entered in science fairs in addition to the official IC state finals. Like robotics competitions such as FIRST Robotics and FIRST Lego League, IC aims at broadening participation in STEM and getting kids excited about engineering [10, 11]. However, robotics teams can be expensive with respect to both equipment and registration fees, which may limit participation from some schools, [12] and the effects on students are not well-studied. There are nascent studies on coaches and college student mentors, [13] and some perceive typical robotics competitions as being narrow in scope, possibly alienating some students [14]. In an effort to broaden interest beyond robotics, FIRST has begun offering a Future Innovator Award to celebrate student invention [15]. Many other sponsored invention competitions exist, such as the Spark!Lab Invent It Competition [16], for which K-12 students are eligible. However, the IC is unique in that it provides a scaffolded but flexible approach for teachers to guide students of various ages through an open-ended invention process with the added benefit of a strong partnership with Georgia Tech. That is, the InVenture Challenge is an *ecosystem* model consisting of university, industry, and community partners who empower *teachers* and students to tackle an open-ended design challenge in a *domain of the students' choosing*.

InVenture Challenge is flexible in that teachers are free to implement lessons as they see fit, in science curriculum, math curriculum, engineering or research classes, target or gifted programs, as an extra-curricular activity, or as an independent study. As compared to traditional science fairs, the IC explicitly encourages engineering, collaboration, communication, invention, and entrepreneurship as much as core content and research. The lessons related to engineering design do not require specific math or science content; rather, they are process-centric. Participation in the IC may support teachers in meeting the NGSS engineering design standards, but more broadly, encourages the students to engage in empathy, collaboration, communication, problem-solving, creativity, cross-disciplinary thinking, and learning from failure. As a support mechanism, Georgia Tech serves as a university partner to provide curriculum materials, mentoring, feedback on student pitches, professional development, a final competition, and tours of Georgia Tech facilities. IC materials are aimed at making open-ended projects more manageable for both teachers and students who may not be used to problem or project-based pedagogy given the current emphasis on standards-based instruction. Finally, and maybe most importantly, students are free to work on a project of their choosing—there are no required themes or disciplines. We believe that keeping the projects in a currency of the students' choosing helps boost student engagement and willingness to see a difficult challenge through to completion [17].

3. InVenture Challenge: implementation and events

3.1 Professional development and lesson plans

Any interested teachers are invited to participate in an optional, one-day InVenture Challenge summer workshop that introduces the competition and the design lessons. There, teachers can share best practices and interact with student inventors from the InVenture Prize on Georgia Tech's campus. In year two, ten teachers attended the summer workshop, 15 new teachers attended in year three, and over 40 attended the year four workshops. During the workshop, teams of teachers complete a miniature engineering design challenge and review relevant resources that they and their students will have at each step of the iterative design cycle. In addition to the workshop, teachers are supported through the maintenance of a website with curriculum and other resources, ability to apply for a prototype and field trip grant, and access to an InVenture Challenge facilitator. Currently, high school and grade school lesson plans are available as free downloads on the InVenture Challenge website [18]. The lesson plans are grounded in relevant standards and were developed by classroom teachers in Georgia. Teachers can also use video footage from past GT InVenture Prize competitions to teach students how to pitch their ideas.

Teachers are not required to use the lesson plans to participate in the InVenture Challenge but can pick and choose lessons as needed for their classrooms. The first lesson helps teachers serve as a facilitator as students discover their design challenge. Next, teachers help students empathize with their potential user and identify authentic needs. After focusing on the user, students develop concise engineering design problem statements targeting user needs. A lesson plan to facilitate a patent search and start the discussion of intellectual property follows. Teachers then lead brainstorming sessions where students review possible solutions. Finally, students prototype, test, and evaluate their designs. The iterative design cycle is emphasized throughout the lesson plans. A final 'launch' lesson encourages students to share their design process and product with others and consider manufacturing and potential markets.

3.2 Pitch practice and virtual mentoring

Before the state finals, students receive feedback on their ideas from Georgia Tech professors and students during an online pitch practice in November or December. Past pitch practices have been facilitated using Adobe Connect software. Students deliver a 3–5 minute pitch of their idea as well as any prototyping up to that point before being asked questions and receiving advice from the professionals. For year three, six schools chose to participate in pitch day; it happened that the top teams for year three (top elementary and top two high school) had all participated in pitch day. Students also have the opportunity to witness undergraduate innovation at Georgia Tech's Fall Capstone Expo and the Technology Association of Georgia's Manufacturing Day.

3.3 InVenture challenge state finals

For the past two years, the top three student teams from each participating school were invited to compete with their projects at the IC state finals held on Georgia Tech's campus in April. The students' engineering design projects are judged based on practicality, knowledge base of the relevant science, design-based thinking, creativity, marketability, social responsibility, enthusiasm, and communication. Some examples of 2015 student projects included: a pacifier designed for better weaning, an app for AP Chemistry students to study their materials, a toothbrush holder that would prevent buildup in the bottom of a cup, a new way to navigate online movie selections, and a way to filter fertilizers from runoff water using all natural materials. The state finals are judged by members of the Georgia Tech community as well as industry professionals and government representatives. The top ten teams are recognized, and the top team for each division (e.g. high school) receives technology-related prizes such as 3D Doodle Pens or iPads. Students coming to Georgia Tech to compete with their inventions are also invited to stay for the live filming of the Georgia Tech InVenture Prize and are sometimes featured in the television broadcast. This event is a celebration of engineering and invention and an opportunity for students to see themselves on a college campus like Georgia Tech's.

4. Guiding questions

In this paper, we seek to address the following two guiding questions using data collected from teachers during year three of implementation:

1. Does participation in the InVenture Challenge increase teachers' self-efficacy and engagement in teaching engineering and entrepreneurship?
2. What benefits to students do teachers perceive as a result of the InVenture Challenge?

5. Data collection and analysis methods

The instruments used for this study include a teacher survey and a focus group protocol, both of which were approved by Georgia Tech's Institutional Review Board. The survey includes locally developed items on implementation and perceived student outcomes as well as items from validated instruments on self-efficacy for teaching engineering and entrepreneurship and overall work engagement. Self-efficacy for teaching engineering was measured with the Teaching Engineering Self-Efficacy Scale. The 23-item version of this scale used in the current study was validated on a sample of nearly 300 K-12 teachers; Cronbach's alpha values ranged from 0.89 to 0.96 for the four subscales (content knowledge, engagement, discipline, outcome expectancy), and the overall Cronbach's alpha value for the full scale was 0.98, indicating a very high level of internal consistency reliability [19]. A subset of items from this instrument was modified to measure self-efficacy for teaching entrepreneurship topics.

The Utretch Work Engagement Scale was used to assess teachers' overall level of engagement with their jobs. The 9-item version of this scale used in the current study was validated in a series of studies with a total sample of over 14,000 employees from a variety of countries and employment settings; Cronbach's alpha values on the 9-item scale from employee samples across countries were all above 0.80, indicating an acceptable level of internal consistency reliability [20]. A set of newly developed items was included to assess teachers' perceptions of whether and to what extent participating in the program has impacted their students' skills, interests, and knowledge.

The survey was administered using an online platform following the 2015 InVenture Challenge state finals. Survey results were received from eight teachers out of 28—even teachers who did not have students finish projects were invited to participate and provide feedback. Of the eight teachers who responded, half are elementary school teachers and half are high school teachers. Simple descriptive statistical analyses were conducted, including calculations of the mean and standard deviation for each survey item. These values were also calculated separately and compared across the elementary and high school teachers, but statistical comparisons across groups (e.g., t-tests) were not conducted due to the small sample size of four respondents each in the elementary school and high school teacher groups. Results on both individual items and subscales and full scales where appropriate were calculated and are presented and discussed below.

Additionally, two focus groups were conducted with teachers during the state finals competition. Focus group questions were designed to target teachers' experiences with implementing the program and their perceptions of how participating in the program has impacted both their teaching and their students' learning and interests. The elementary teacher focus group included 5 teachers, and the high school teacher focus group included 7 teachers. Qualitative data from the focus groups were analyzed using thematic analysis. Thematic analysis entails a systematic review of the data and identification of a relevant set of themes present within the data [21]. Illustrative quotes that correspond to each theme were also identified; a selection of these is presented later in the paper. Data from both sources were used to inform revisions to the program for the following year.

6. Results & Discussion

The results from the survey data and the results from the focus group data are treated separately in this paper. There is partial overlap in the groups of teachers responding to the survey and participating in the focus groups. These were separate, voluntary instruments administered at different times; however, the emerging themes and feedback were relatively consistent across both instruments. In addition, the sample included both elementary and high school teachers. The authors recognize that these are different populations; however, the sample size is very small and does not lend itself to statistical analysis of differences between the elementary and high school teacher groups, and the guiding questions do not focus on differences between these two teacher groups. We will present differences in these populations where appropriate, with the caveat that the results do not reflect statistical tests for group differences.

6.1 InVenture challenge implementation details

Because the InVenture Challenge is flexible in its delivery, implementation details for InVenture Challenge varied widely for the 2014–2015 school year. All elementary school teachers who responded to the survey reported having implemented the program in their gifted classrooms. At the high school level, the program was implemented either through in-class projects (e.g., in AP Physics class), after-school clubs and activities (e.g., Technology Student Association), or independently on students' own time. The number of students each teacher worked with on InVenture Challenge also varied, ranging from six to more than 30 students being mentored by a teacher.

The implementation schedule also varied widely. Most teachers (five of eight) implemented the program over the course of roughly one semester, but others reported time frames varying from one week to an entire academic year. Most teachers (six of eight) worked with students between two and four days per week, while the other two worked with students less than one day per week. The duration for these meetings was most frequently reported to be between one and two hours (reported by four teachers), with a minimum of less than one hour (two teachers) and a maximum of a full school day (one teacher).

Of the eight teachers who responded to the survey, five teachers participated in the InVenture Challenge state finals at Georgia Tech, five participated in InVenture Challenge workshops, four participated in pitch day, and four attended the Georgia Tech Capstone Expo. The majority of teachers (six of eight) also reported being involved in other gifted and/or STEM-related activities at their schools.

While this initial survey data is largely descriptive, it is helpful in the development of implementation models that can be delivered at scale.

6.2 Teaching engineering content & teaching entrepreneurship content scales

The IC relies heavily on principles from both engineering and entrepreneurship to guide the students through identifying a problem and designing a solution with a particular client or target market in mind. Because of this, teachers need to address content or processes from both subject areas when facilitating the students' design processes and pitch development. In this portion of the survey, teachers' self-efficacy with respect to teaching engineering content and entrepreneurship content were measured separately to examine any differences between the two subject areas.

The Teaching Engineering Self-Efficacy Scale (TESS) is a validated instrument including items related to teachers' comfort level with planning, implementing, and managing the delivery of engineering content in the classroom as measured on a six-point Likert-type response scale ranging from Strongly Disagree to Strongly Agree [19]. Similarly, the Teaching Entrepreneurship Self-Efficacy Scale is a modified version of the engineering instrument intended to measure teachers' comfort with teaching entrepreneurship. Descriptive statistics (means and standard deviations) of teacher responses to each item for the TESS and the entrepreneurship scale, along with the original items, are contained in Tables 1 and 2, respectively. For the validated TESS, mean scores on each subscale and across the full scale are also provided.

In general, mean responses on the entrepreneurship items were lower than mean responses on the engineering items, indicating that our teachers may generally feel less confident in their ability to teach students about entrepreneurship as compared to engineering. However, teachers see entrepreneurship as valuable, indicated by the high mean response to "I feel it is valuable to teach entrepreneurial thinking to my students" (mean = 5.57). This information has informed updates to the teacher workshops and materials to better guide teachers through entrepreneurship and intellectual property issues.

With respect to the TESS subscales, the average score on the engagement subscale was approximately $\frac{1}{2}$ point higher than the average score on any other subscale. This suggests that, compared to other aspects of teaching engineering, teachers feel somewhat more confident in their ability to engage students in engineering activities, specifically with respect to promoting a positive attitude towards engineering, critical and creative thinking, and teamwork.

A common thread across both the engineering and entrepreneurship self-efficacy scale was the need for more time to plan lessons, as indicated by a generally lower mean response to that item as compared to others (mean = 4.50 for engineering and mean = 4.50 for entrepreneurship). It is our hope that the InVenture Challenge curriculum materials, now available for both grade school and high school, will ease the burden on teachers, particularly returning teachers.

Table 1. Teaching Engineering Self-Efficacy Scale

Teaching Engineering Self-Efficacy Scale			
Item:	**N**	**Mean**	**SD**
1. I can discuss with my class how engineering is connected to my daily life.	7	5.57	0.53
2. I can recognize and appreciate the engineering concepts in all subject areas.	8	5.38	0.92
3. I can spend the time necessary to plan engineering lessons for my class.	8	4.50	1.41
4. I can employ engineering activities in my classroom effectively.	8	5.00	1.31
5. I can craft good questions about engineering for my students.	8	5.00	0.93
6. I can discuss how given criteria affect the outcome of an engineering project.	7	5.14	0.69
7. I can guide my students' solution development with the engineering design process.	8	5.13	0.83
8. I can gauge student comprehension of the engineering materials that I have taught.	7	5.29	0.49
9. I can assess my students' engineering products.	8	5.13	0.35
10. I can promote a positive attitude toward engineering learning in my students.	8	5.75	0.46
11. I can encourage my students to think critically when practicing engineering.	8	5.75	0.46
12. I can encourage my students to interact with each other when participating in engineering activities.	8	5.63	0.74
13. I can encourage my students to think creatively during engineering activities and lessons.	8	5.63	0.52
14. I can calm a student who is disruptive or noisy during engineering activities.	7	5.57	0.53
15. I can get through to students with behavior problems while teaching engineering.	7	5.14	0.69
16. I can keep a few problem students from ruining an entire engineering lesson.	7	5.14	0.69
17. I can control disruptive behavior in my classroom during engineering activities.	7	5.14	0.69
18. I can establish a classroom management system for engineering activities.	7	5.29	0.76
19. When a student gets a better grade in engineering than he/she usually gets, it is often because I found better ways of teaching that student.	7	5.14	0.69
20. When my students do better than usual in engineering, it is often because I exerted a little extra effort.	7	5.29	0.76
21. If I increase my effort in engineering teaching, I see significant change in students' engineering achievement.	6	5.17	0.75
22. I am generally responsible for my students' achievements in engineering.	6	4.67	1.03
23. My effectiveness in engineering teaching can influence the achievement of students with low motivation.	7	5.29	0.49
Content Knowledge Subscale (Items 1–9).	8	5.12	0.64
Engagement Subscale (Items 10–13).	8	5.69	0.51
Discipline Subscale (Items 14–18).	7	5.26	0.62
Outcome Expectancy Subscale (Items 19–23).	7	5.11	0.55
Full TESS Scale.	8	5.21	0.53

Table 2. Teaching Entrepreneurship Self-Efficacy Scale

Teaching Entrepreneurship Self-Efficacy Scale			
Item:	**N**	**Mean**	**SD**
I can discuss with my class how business and entrepreneurship affects my daily life.	8	5.38	0.74
I can help my students understand how different products appeal to different audiences.	8	5.38	0.74
I can spend the time necessary to plan entrepreneurship lessons for my class.	6	4.50	1.22
I can employ entrepreneurship activities in my classroom effectively.	6	4.50	1.22
I can craft good questions about entrepreneurship for my students.	7	4.57	0.98
I can discuss how design requirements for an engineering project relate to customer satisfaction and business success.	8	4.63	1.51
I am comfortable providing feedback about pricing and marketing aspects of student projects.	7	3.86	1.46
I can gauge student comprehension of the entrepreneurship concepts that I have taught.	5	4.60	0.89
I can assess my students' entrepreneurial thinking through activities, quizzes, class discussions, etc.	5	4.80	1.10
I feel it is valuable to teach entrepreneurial thinking to my students.	7	5.57	0.53

Table 3. Utrecht Work Engagement Scale

Utrecht Work Engagement Scale			
Item:	**N**	**Mean**	**SD**
At my work, I feel bursting with energy.	8	5.00	0.76
At my job, I feel strong and vigorous.	8	5.00	0.76
I am enthusiastic about my job.	8	5.88	0.35
My job inspires me.	8	5.63	0.52
When I get up in the morning, I feel like going to work.	8	5.13	0.83
I feel happy when I am working intensely.	8	5.38	0.52
I am proud of the work that I do.	8	5.63	0.52
I am immersed in my work.	8	5.63	0.74
I get carried away when I am working.	8	5.50	0.76
Vigor Subscale (Items 1, 2, and 5).	8	5.04	0.72
Dedication Subscale (Items 3, 4, and 7).	8	5.71	0.33
Absorption Subscale (Items 6, 8, and 9).	8	5.50	0.50
Full Work Engagement Scale.	8	5.42	0.41

Finally, it is worth noting the relatively low mean response to the TESS item "I am generally responsible for my students' achievements in engineering" (mean = 4.67). The interpretation of this item is not entirely clear—one interpretation is that teachers are acting more as facilitators during engineering lessons and projects, and that students are taking more responsibility for their own success. This interpretation is supported by focus group data. For example, one high school teacher commented, 'I've transitioned my teaching . . . to more of me as a facilitator. I felt like I wasn't being a good teacher at first because I wasn't giving them information. But I come around and ask those higher order thinking questions.' If this interpretation is correct, then this is a positive outcome; this can be further investigated in future focus groups.

6.3 *Utretcht work engagement scale*

The Utrecht Work Engagement Scale measures work engagement, defined as "a positive, fulfilling work-related state of mind", along three facets: vigor, dedication, and absorption [20]. Mean responses and corresponding standard deviations for each item are displayed in Table 3. Teachers in this sample report a high level of engagement at work, which is not surprising as this is a self-selected group of highly involved teachers. Mean responses on the nine work engagement items all fell at 5.0 or higher on a 6-point Likert-type scale ranging from Strongly Disagree to Strongly Agree. The subscale results indicate that teachers' mean response on the Vigor subscale is roughly $\frac{1}{2}$ point lower than the other two subscale scores.

6.4 *Student work scale*

The Student Work Scale consists of locally developed items intended to assess teacher perceptions of whether participation in InVenture Challenge has increased students' interests and abilities in engineering and entrepreneurship as well as teamwork and communication. Mean responses and corresponding standard deviations for each item are displayed in Table 4. Seven of the eight student

Table 4. Student Work Scale

Student Work Scale			
Item:	**N**	**Mean**	**SD**
Participating in InVenture Challenge has increased my students' enthusiasm for learning about engineering.	8	5.63	0.52
Participating in InVenture Challenge has increased my students' enthusiasm for learning about entrepreneurship/innovation.	8	5.50	0.53
Participating in InVenture Challenge has increased my students' ability to clearly present their ideas to others.	8	5.50	0.76
Participating in InVenture Challenge has increased my students' ability to work effectively in teams.	8	5.50	0.53
Participating in InVenture Challenge has increased my students' knowledge of the engineering design process.	8	5.50	0.53
Participating in InVenture Challenge has increased my students' knowledge of how products are made.	8	5.13	0.64
Participating in InVenture Challenge has increased my students' knowledge of how to design an effective sales pitch.	8	5.25	0.46
Participating in InVenture Challenge has increased my students' understanding of how to start a business.	8	3.75	1.39

work items had means of 5.0 or higher on the same 6 point Likert-type scale described previously. However, one item had a substantially lower mean of 3.75: "Participating in InVenture Challenge has increased my students' understanding of how to start a business." This is in line with teachers' ratings of their own effectiveness as lower for entrepreneurship teaching as compared to engineering teaching and may reflect the teachers' feelings of not knowing how to guide students through the process of starting a business. For example, one elementary school teacher remarked during the focus group that she would have 'no idea' where to start if a student group wanted to file a patent. To that end, we have partnered with a local patent lawyer to provide information on the provisional patent process and will be offering some grants for promising inventions prior to the InVenture Challenge state finals in 2016. We also plan to include more explicit lessons about the basics of intellectual property on our website.

6.5 Grade level comparisons on survey items

As mentioned previously, the small sample size does not allow for statistical comparison between the elementary and high school teacher groups. In order to understand potential differences in the two groups, trends were examined in mean survey item responses. On the Teaching Engineering Self-Efficacy Scale, grade level differences were minor, with mean scores on the four subscales varying between elementary and high school teachers by 0.25 or less (on a 6 point scale), but always with the elementary scores being higher. Conversely, when scores for all of the locally developed teaching entrepreneurship self-efficacy items were averaged into a single scale score, the mean scale response among high school teachers was almost 0.50 points higher (on a 6 point scale) than the mean scale response among elementary school teachers. This may indicate higher self-efficacy for teaching entrepreneurship among the high school teachers as compared to elementary school teachers.

On the Work Engagement scale, the teacher groups had comparable mean scores on the full scale as well as the vigor and dedication subscales. On the absorption subscale, a 0.67 point difference was present, with high school teachers reporting higher levels of absorption in their work as compared to elementary school teachers. Lastly, mean score differences on student improvement items (mean difference of 0.56 points) indicate elementary school teachers reporting a slightly stronger level of agreement that participating in InVenture Challenge had improved various outcomes for their students.

In conclusion, comparisons of elementary and high school teacher data provide some support for the following: (1) high school teachers have higher self-efficacy for teaching entrepreneurship; (2) high school teachers are more absorbed in their work; (3) elementary school teachers provide a higher level of agreement that participating in InVenture Challenge is associated with improved outcomes for their students. It should be noted that these results are derived from an examination of trends present in the data rather than from statistical analyses. It should also be noted that student populations for the teacher groups vary, as all elementary school teachers in this sample implemented InVenture Challenge with students in the gifted program, while high school teachers implemented InVenture Challenge with students from more varied ability levels.

6.6 Qualitative teacher feedback

Survey respondents were given open-ended items about the InVenture Challenge in terms of what they valued and what could be improved. For brevity, themes from these responses are combined with themes from the two focus groups, which took place during the InVenture Challenge state finals on April 1, 2015. From all qualitative data sources, some common themes emerged and are discussed in more detail with illustrative quotes below.

Student Engagement, Interest in Engineering, Learning

> *They learned a lot, they grew a lot, and that's really our goal—to get them to think, process, and grow as a person . . .*

Teachers across grade levels commented that the program elicited a high level of student engagement and interest in engineering. As quoted by one of the high school teachers,

> *My kids came back and said that we really need an engineering class at our school.*

She lamented that they still do not have one, so she implements the IC as an extra-curricular activity.

The elementary school teachers felt that students gained an expanded view of engineering by researching types of engineering and by seeing older students participating and succeeding in engineering through venues such as the Georgia Tech Capstone Expo [22]. Teachers commented that some elementary students initially thought that they would not enjoy engineering, but seeing different types of engineers working together changed their perception.

Partnership and Support from Georgia Tech

One teacher commented about seeing the Georgia Tech InVenture Prize live filming, *When you watch those kids [Georgia Tech students] on stage—that could be you [your students] in a few years.*

Teachers across both levels appreciated the connection to Georgia Tech and getting students involved beyond their own classrooms. Several of the teachers had personal connections with Georgia Tech's InVenture Prize or had seen the InVenture Prize on TV, which was how they got involved. Teachers enjoyed taking the students to Tech's campus for field trips so that the students could see themselves there, as future engineers or simply as college students.

Teachers generally wanted an even stronger connection with Georgia Tech, including video resources, direct mentorship, webinars, and guest speakers. To do this in a scalable way, we are piloting different digital mentoring strategies to see if any are effective, in addition to Pitch Day. One strategy being piloted for 2015–16 is a web forum where teachers and students can 'ask an expert' from Georgia Tech or from industry for feedback on a variety of topics including prototyping, business and marketing, and the engineering process.

Professional Development and Resources

I like having a curriculum framework to kind of follow, because we've done things like inventions, but it made it easier to do.

Teachers saw value in teaching their students about the engineering design process with its detailed steps, which helped students organize their ideas. Elementary teachers indicated that research was difficult for their students, particularly patent searches, as the language is not easily accessible to young audiences. They also expressed some difficulties in prototyping, depending on the student's choice of project. They realized that not all of the prototypes were real or testable. A similar sentiment was echoed by the high school teachers who had to decide whether or not to steer students away from projects that would require too many resources to implement at scale. In addition, high school and elementary school teachers noted the importance of self-reflection but also commented on the difficulty in getting students to do it. Some high school teachers tried to have students keep an engineering notebook, but most noted room for improvement in the areas of documentation and reflection. To address this need, we will be piloting an electronic design log with some of our returning teachers and asking for feedback on its usefulness.

Social Impact and Empathy

It [InVenture Challenge] allowed students to be more aware of what's going on in society.

Elementary teachers stated that it is difficult for young students to look outside themselves and think about other people. They felt that the 'empathy' lesson plans helped students think about problems that were not just their own. High school teachers noted a lot of personal stories making their way into the classroom. High school students also seemed inspired by the GT InVenture Prize projects that were aimed at societal issues, like sanitation and safety. Teachers noted seeing more projects of that nature from their own students after seeing the college students' ideas.

Broadening Participation

One teacher who teaches AP Physics C noted,

The problem is, for the seniors, I feel like I'm preaching to the choir. These kids have already decided they like physics; lots of them are already accepted to Georgia Tech and other technology schools. It seems like I need to try to get this in at an earlier level.

Elementary school students seemed to be inspired by seeing older students succeeding in engineering, especially women. In the elementary gifted classes, there are more female than male students; in the high school courses, the trend tends to be the opposite. High school teachers were supportive of implementing the InVenture Challenge earlier in high school, and in elementary and middle schools, to recruit young women into STEM classes.

Teaching Style and Comparison with Other Activities

The high school teachers quickly drew comparisons to other activities they had been implementing before InVenture, such as science fairs, lab activities, and classic challenges like egg drop and bridge building. One teacher commented,

. . . with the cookie cutter labs we do, there's a right or a wrong. So having students see that they don't have to be focused on an answer but on the process has been really important.

They appreciated the room for innovation and creativity afforded by the InVenture Challenge, even if it made some students uncomfortable because of the lack of rules or a clear way to get a good grade. They felt that it forced the students to become more comfortable with failure and to be more creative. One high school teacher noted,

Failures are part of the process. Learning that has been tremendous for them—that it's okay if we keep trying.

Some students realize that their project can persist after the IC is over; they can enter again in future years with a better prototype or a new idea, or they can pursue a patent or a business whether or not they win any accolades.

Collaboration and Teamwork
Teachers appreciated the program as an avenue to encourage teamwork among their students. The elementary school students started recognizing their own strengths and tried to partner with other students who had different strengths. One teacher commented,

> *I told them [my kids], 'really think about your strengths and weaknesses' And they know each other pretty well by 5th grade, like 'you're the artsy one, you're the logical one.' And for the most part, they really did mix boy and girl. They're like, 'ok, [student name]'s creative. I'm gonna pull her in.'*

High school teachers noted opportunities for experienced students to serve as mentors for new teams in future years. One teacher said,

> *That's what my girls last year did that won. They made themselves available to the people this year to talk to them about what all they went through.*

Authenticity

> *This had such a real application.*

Teachers at the elementary school appreciated that the IC provided a high stakes learning experience for students and cited examples of students finding out that their ideas had already been patented, illustrating the need for thorough research. Teachers across all grade levels commented that they felt their students were taken seriously and treated like adults throughout the IC, including the pitch day and state finals.

One high school teacher made the following comment about watching her students present at a VIP reception for the InVenture Challenge:

> *That was the most exciting professional experience I've ever had in my life. Because watching my students talk to those VIP's, selling their product, just blew me away. It was amazing. Our kids don't get those opportunities to project themselves in the adult world quite like that and sell themselves. So it was a really powerful moment for those that get to come here.*

7. Conclusions

Based on the data presented, the InVenture Challenge is effectively engaging students in engineering and entrepreneurship through invention. Recall that the guiding questions for this paper are as follows:

1. Does participation in the InVenture Challenge increase teachers' self-efficacy and engagement in teaching engineering and entrepreneurship?
2. What benefits to students do teachers perceive as a result of the InVenture Challenge?

With respect to the first guiding question, the data presented in this paper indicates that teachers generally feel more comfortable teaching engineering than entrepreneurship and that some teachers successfully evolved into a facilitator role while enacting the IC in their classrooms. Additionally, across survey items, teachers express high levels of self-efficacy for teaching both engineering and entrepreneurship, report a high level of engagement in their work, and indicate that they saw improvements in their students across a variety of outcomes as a result of their participation in InVenture Challenge. However, we cannot assess whether the InVenture Challenge is related to growth in these areas due to a lack of pre and post-participation data to allow for comparisons of perceptions before and after participation in IC.

Examination of trends in the comparisons of elementary and high school teacher groups also suggested that there are grade level differences in self-efficacy for teaching entrepreneurship, feelings of absorption in one's work, and perceived improvements in student outcomes as a result of participation in InVenture Challenge. The extent to which these trends will generalize beyond the current small sample is an area for future research.

With respect to the second guiding question, teachers cited many perceived student benefits as evidenced by the Student Work Scale and the qualitative data, including exposure to engineering, learning through iteration, collaboration, teamwork, creativity, and others.

8. Future work

Based on these initial results from teacher surveys and focus groups, we will be collecting data from a larger sample of teachers in 2015–16 and beyond to continue to look for generalizable outcomes. More importantly, students will need to be interviewed and surveyed directly in future years to better understand the impacts of IC participation on student learning. Surveying and interviewing students requires special institutional review board approval due to the research subjects being minors and will likely require the development of new instruments that allow us to measure appropriate student outcomes. This initial data from the teachers allows us to begin to formulate testable hypotheses for which rigorous research studies can be defined.

The InVenture Challenge program will continue to grow with guidance from the teacher feedback and focus groups. Already in 2016, 60 teams from 30 different schools in Georgia participated in the InVenture Challenge state finals, including middle schools for the first time. The focus group themes described above were used to develop new focus group and in-depth interview protocols for more specific research questions. This data will be analyzed and presented in future publications.

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