Increasing the STEM pipeline: Impact of a multi-faceted STEM organization

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ABSTRACT
Aggie STEM serves K-12 teachers and students by providing professional development (PD) over a wide range of STEM educational topics in a variety of formats and settings. The goal of the PD is to provide teachers with the tools they need for effective classroom instruction, with the objective of increasing the STEM pipeline by providing students with more engaging instruction in formal and informal settings. This paper describes Aggie STEM’s role in improving STEM instruction and experiences through PD for teachers and summer camp for students. By supporting teachers to improve classroom instruction, Aggie STEM impacted more students than was possible by teaching secondary students in the classroom. In a single year, through PD to more than 800 teachers, the number of students whose STEM knowledge was enriched exceeded 24,000.

INTRODUCTION

The United States, along with other countries around the world, has a goal of increasing STEM majors to meet the expanding need for workers who are prepared to compete in an increasingly technological world, specifically requiring the knowledge and problem-solving skills of various fields of engineering. Student retention in engineering is a continuing problem, but an expansion of recruiting strategies is the first step to be accomplished. Aggie STEM is an organization that has as one of its goals the task of improving students’ interest in STEM subjects and thereby recruiting STEM majors through 1) engaging secondary students in active learning in Aggie STEM’s Summer Camp and in classrooms throughout the US, and 2) helping secondary STEM teachers use teaching strategies with real world problems that interest students. Studies have shown that Project-based Learning (PBL) is not only effective in engaging students in the classroom, but when implemented with high fidelity improves student performance in mathematics and science. In order to effect changes in secondary STEM classrooms so that students experience high quality instruction, PD that a) increases teacher content and pedagogical content knowledge in mathematics and science, b) provides collaboration opportunities, and c) relates to classroom instruction is necessary.

RESEARCH QUESTION AND METHODS

The research question was “What strategies can an organization employ to maximize impact on the STEM pipeline?” Over the past eight years, Aggie STEM has increased the number and types of research-based strategies that increase secondary student interest in STEM majors and careers. As a T-STEM Center in Texas, Aggie STEM served the T-STEM academies by providing PD in Project-Based learning. Teachers created professional learning communities and learned how to integrate appropriate technology in their mathematics and science lessons. A student summer camp was established to give students an opportunity to work with STEM professors, and a Teacher Boot Camp was added alongside the student camp to provide further opportunities for PD. With this model, teachers have the opportunity to see students like their own engaged in PBL, and they discuss the teaching strategies used in debrief sessions with STEM faculty. The model was recently expanded to utilize technology for teachers across Texas to view live feeds from their schools and homes. Aggie STEM has developed online PD modules and continues to seek avenues to impact teachers and students world-wide.

DIRECT IMPACT ON SECONDARY STUDENTS

Students have been influenced positively about STEM majors and careers through opportunities to interact with STEM faculty, staff, graduate students, and undergraduate students. Those opportunities were afforded primarily through three venues: a summer camp for secondary students, classroom visits to secondary schools by faculty, and internships or individual research projects led by faculty.

Summer camp

Through the Aggie STEM Summer Camp for secondary students, the faculty and staff of Aggie STEM impact student interest in STEM subjects and careers. Students who attended the camp in the summer of 2014 experienced STEM Project-based Learning (PBL) in mini courses centered around bridge building, plant biology, cosmetic chemistry, robotics, and 3-D printing. In addition, they had the opportunity to attend a physics show highlighting interesting physical properties that scientists research and explore and to visit the local television station and create a short video. They also completed mini courses in mathematics and science preparation for national tests, statistics, and basic cryptography. Students worked with engineering and mathematics education faculty and had opportunities to talk with them about their work. Through the experiences at the two-week camp, students gained knowledge about STEM careers and different research opportunities in STEM fields.

Visiting classrooms

Aggie STEM faculty had have occasion to visit secondary mathematics and science classrooms of teacher participants in PD. Students in the classroom not only have the opportunity to meet STEM college faculty and researchers, they were often given opportunities to ask them questions about the work that they do on a daily basis. Although this opportunity for interaction with students was for
shorter periods of time than that in the summer camp, it provided an additional avenue for faculty to interact with students and influence their attitudes about STEM majors and careers.

**Internships and research projects**

By request of a local Texas STEM Academy campus, Aggie STEM faculty have recently set up opportunities for internships and research projects for interested students who wish to visit the university campus and work with faculty and graduate students on special research projects appropriate for their individual interests, background, and abilities.

**IMPACT ON SECONDARY STUDENTS THROUGH STEM TEACHERS**

Aggie STEM operates as an umbrella, encompassing several funded activities (see Figure 1). At the core is a T-STEM center funded by the Texas Education Agency, along with the T-STEM coalition (of the seven T-STEM centers). In addition, Aggie STEM plays a central role in the STEM Collaborative and Teacher Quality Grant Program, both funded by the Texas Higher Education Coordinating Board. There is a great deal of synergy between the Summer Camp (offered for students) and the Boot Camp (offered for predominately T-STEM academy teachers). In addition, portions of the Summer Camp classes are streamed live and used in the PD component of the Teacher Quality Grant, and of the STEM Collaborative. Captured video also has potential for use in future PD offered by Aggie STEM under any current or future effort.

![Figure 1. The Aggie STEM Impact Model.](image)

**STEM Collaborative for Teacher Professional Learning**

The STEM Collaborative is funded by the Texas Higher Education Coordinating Board to serve all secondary STEM teachers in Texas. As part of the STEM Collaborative for Teacher Professional Learning, STEM teachers participate in learning opportunities to assist them in developing and implementing high-yield teaching strategies specific to STEM education. In addition, participants enjoy peer support and peer mentoring through a professional learning STEM network. STEM teachers participate through two options: An individual online certificate in STEM Teaching (64 Continuing Professional Education [CPE] credits); and as a team in a teacher professional learning network (TPLN) with a series of PD opportunities throughout the year (100 CPE). STEM Teachers teach one or more periods of science or mathematics, or teach one or more periods of technology (e.g., but not limited to – computers or robotics), or teach one or more periods of Career and Technology Education (e.g., but not limited to GIS, engineering, drafting, and electronics).

**STEM coalition**

The Texas STEM Coalition represents the seven T-STEM Centers in Texas. While all centers offer similar core services, each offers unique specialization. Through the coalition, the centers are able to broaden
the services available to each of the 90+ T-STEM academies in the state of Texas. Each T-STEM academy is assigned to a center; however, all are free to seek services from any of the seven centers. In addition, the coalition offers a STEM conference each year. This conference is open to teachers and administrators of all T-STEM academies, as well as other middle and high school campuses.

**T-STEM center**
As a Texas STEM center with funding from the Texas Education Agency, Aggie STEM was charged with the task of providing PD to support teachers of Texas STEM Academies in improving instruction and integrating STEM and other subjects through PBL. Although instruction focused on the understanding of, logistics, and methods for integrated STEM PBL, PD for various topics that supported implementation of STEM PBL were provided. Specifically, those topics included establishing and maintaining professional learning communities, student-centered classrooms, formative and summative assessment, grading with rubrics, and training on using various technologies in the classroom. Besides the set of topics listed, Aggie STEM provides customized PD as requested by each T-STEM Academy in order to support their implementation of STEM PBL. In addition, using other available funding, Aggie STEM has begun developing an array of interactive online PD modules for which individual teachers may register. The modules are currently free of charge to teachers in T-STEM Academies, but teachers on other secondary campuses may register for a small fee. These help us reach teachers that do not work for T-STEM Academies, teachers in districts without travel budgets, teachers in remote districts, and isolated teachers in districts (the only teacher in a district interested in PBL). Currently, Aggie STEM serves teachers concentrated over more than one-third of the area of the state of Texas as well as students and teachers in other states and countries (see Figure 2).

![Map of Aggie STEM Regional Influence.](image)

**Aggie STEM Teacher Boot Camp**
In conjunction with the Aggie STEM Summer Camp for secondary students, a camp for teachers provides opportunities to 1) observe students engaged in PBL, 2) observe faculty facilitating PBL lessons, and 3) learn how to write PBL lessons for the classroom. In the first iteration of the teacher camp, the teachers entered the classroom to observe students. They were able to see how STEM professors engaged students in inquiry learning and facilitated student-directed activities. In addition, students were able to share their thoughts and experiences with teachers during breaks. Because the number of teachers was small, their presence in the classroom was not disruptive. However, as interest in the teacher camp grew, new strategies were required. Technology specialists were cooperative in finding solutions and purchasing required hardware and software to implement the new plan. Teachers gathered in a separate room from students but watched a live feed of the student classroom. They were prepared for what they were going to observe and guided through the observation using an instrument designed to facilitate their observation. A debriefing period followed for discussion about the teaching
strategies they observed. Teachers were then provided instruction on designing classroom PBL lessons and guided through the process to prepare the lessons they planned to use during the academic year.

**Teacher Quality Grant**

The model from the Aggie STEM Teacher Boot Camp was modified for participants in the Teacher Quality Grant, funded by the Texas Higher Education Coordinating Board. More than 50 teachers over an 85,000-square-mile area observed the secondary students in the summer camp remotely. Teachers received a link to the live feed of the PBL classroom. In addition, they logged on to a robust, flexible conferencing online environment. Over headsets with microphones, they discussed with STEM professors the background for the classes they observed. The professors guided them through the observation using the observation instrument, and discussed the strategies they observed and the students’ response to them.

**IMPACT ON SECONDARY STEM TEACHERS THROUGH STUDENTS**

The impact of a multi-pronged approach has a cyclical effect as teachers impact students, and students impact teachers and other students. In addition to the impact on secondary STEM teachers through the PD provided by the STEM Collaborative for Teacher Professional Learning, the STEM Coalition, support to T-STEM academies through grants from the Texas Education Agency, Aggie STEM Teacher Boot Camp and the Teacher Quality Grant Program, there was an impact on the teachers as a result of students who experienced the Aggie STEM Summer Camp and/or Internships and Projects and returned to their secondary classrooms. Relating their experiences and new knowledge about STEM majors and careers created interest in teachers to extend the camp experiences to other students through inquiry learning and providing students with opportunities to work on solutions to real life problems. In addition, the observation of camp students by teachers had an impact as they experienced through the students’ eyes the excitement of learning to use cutting edge technology to produce a meaningful product. Seeing students with characteristics of their own students become more interested in staying focused on learning gave them impetus to make changes in their own classrooms. After fall classes began, after a classroom visit to the teacher’s campus, the teacher explained that her district had decided to provide PBL training to teachers. However, the training consisted of explaining how PBL worked, and many teachers were confused and resistant to trying to implement the new pedagogy. Nevertheless, the teacher who experienced the observation of students engaged in PBL was ready to begin working toward the goal of implementing PBL. She explained that the difference was that the Aggie STEM training had showed them what it looked like in the classroom and guided their observation so that they understood the concept much better.

**RESULTS**

Aggie STEM programs served 857 professionals in the past year. This included 4 elementary school teachers, 223 Middle School teachers, 623 high school teachers, and 7 administrators from 32 T-STEM Academies, and 673 non T-STEM campuses. In addition, our summer camps for students increase in size each year (over 100 students in 2014). More important than size is the impact on the students: increased interest in attending college, increased appreciation for academic preparation, and increased interest in STEM careers.

Student impact was measured through surveys about interest in STEM fields and interviews with individual campers. The Test of Science Related Attitudes (TOSRA) was used to determine science-related student attitudes before and after participation in the 2012 Aggie STEM Summer Camp. The overall average scores increased, and two of the seven attitudes showed statistical significance. Both “normality of scientists” \((p < .001)\) and “enjoyment of science lessons” \((p = .037)\) showed gains for the students surveyed. Based on a survey in 2014, 70% of campers would consider a STEM career that includes knowledge of the arts. Ninety percent of the campers believed problem solving in STEM courses requires creative solutions, and 100% used their own creative and artistic abilities during the camp. A student interviewed in the 2014 summer camp reflected that the camp “definitely” influenced her decision to choose a mathematics major in college. She realized while helping other camps students that she “loved mathematics.”
The impact of STEM-based PD on teachers was two-fold: 1) they were more positive about PBL as a result of observing the increase in student engagement, and 2) they increased their knowledge about STEM PBL with its characteristics and implementation.

Five of six focus groups conducted with teachers who had participated in sustained integrated STEM PBL PD asserted that their students were more engaged in the lessons when they used PBL. Teachers participating in the 2014 Aggie STEM Teacher Boot Camp were involved with observation of students engaged in PBL, discussion of strategies used by instructors facilitating the PBL, and spent time creating or adapting PBL lessons for their classrooms. The pre/post-test of PBL knowledge gains \( (n = 22) \) were statistically significant \((p < .001)\), and practically significant (Cohen’s \( d = 1.06 \)), with the mean increasing from 11.86 \((SD = 2.25)\) to 13.91 \((SD = 1.60)\).

**DISCUSSION**

Aggie STEM is converging on a model for PD that can reach all teachers. In addition, we are seeing the desired positive changes for both teachers and students. More teachers than ever before are receiving STEM PBL PD, they are recognizing the positive effect of a PBL environment on student engagement, and they are learning to implement PBL in their classrooms. Students are participating in and enjoying an academic STEM summer camp, learning about STEM careers, changing attitudes about STEM, and (based on creativity) considering STEM careers.

The efforts described above have reached many teachers, and through them many more students. Nevertheless, much work remains to be done. Turnover of administrators, turnover of teachers, lack of (common) planning time for teachers, and lack of sustained PD continue to hinder implementation efforts. Administrators need training in order to properly support the teachers (PBL is not normal classroom teaching & integrated STEM is covered by commonly used observation instruments). Teachers need training in order to activate PBL in their classrooms (PBL is much different than passing out worksheets). In addition, teachers need to plan together (integrated lessons do - not just happen). Finally, effective PD is sustained PD (transformation is the result of hard work, sustained effort, and perseverance).

**REFERENCES**


