The Texas High School Initiative Aims at STEM Education Reform: Texas Tech University T-STEM Center—Putting the "E" in K-12 STEM Education

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Abstract - **The Texas High School Initiative aims at producing a leading innovative technical workforce in Texas by aligning the education efforts of high school, postsecondary, and economic development entities. The Texas Education Agency (TEA) with the Bill and Melinda Gates Foundation, Micheal and Susan Dell Foundation, and other government and private sector partners have committed $180 million to STEM education reform in Texas. Texas Tech University was awarded funding to create one of five T-STEM Centers to develop innovative curriculum, professional development for teachers, classroom support, and other research-based educational resources in STEM areas. The Centers will identify, document, and disseminate best practices that demonstrate improved teaching and learning in STEM subjects as part of the Texas Innovation Network, which also includes 35 high school T-STEM Academies, and programs to train high school principals and administrators in STEM best practice. The special emphasis of the Texas Tech T-STEM Center is to research, create, and disseminate best practices for innovative teaching and learning using the engineering- design process as an instructional framework for engaging students in rigorous inquiry and project-based learning that emphasizes high level application of mathematics, science, and technology and develop problem solving, critical thinking, teamwork, communication, and other skills needed to succeed in higher education and the workforce. The TTU T-STEM Center will also provide pedagogical training, professional development, and recruitment opportunities for K-12 teachers in STEM fields. With engineering design as its focus, the Texas Tech University T-STEM Center will train teachers to use engineering design in teaching applied math, science and technology. The center's design team, drawn from three successful programs at Texas Tech——the Center for Engineering Outreach, Howard Hughes Medical Institute/Center for the Integration of Science and Education Research (CISER), and the Outdoor Learning Center——is in the process of developing curriculum and professional development that integrates a wide range of expertise and resources at Texas Tech and incorporates national and state STEM standards. This paper will discuss the design, development, and planned implementation of the Texas Tech T-STEM Center.**

Index Terms - K-12 engineering education, STEM Education, professional development, project-based engineering design, teacher training and Texas T-STEM Initiative.

INTRODUCTION

The Texas High School Project [1] is determined to make a radical change in grades 6-12 across the state of Texas. With $180 million designated for the Texas-Science, Technology, Engineering and Math (T-STEM) initiative alone, Texas is establishing thirty-five STEM academies, primarily high schools and some middle schools to develop innovative and effective methods that instill rigorous learning of STEM concepts in the classroom. In addition, five geographically diverse areas of Texas have been awarded funding to establish T-STEM Centers that will train not only the T-STEM academy teachers but any teacher and administrator in the state of Texas on how to integrate rigor into the classroom and still address the Texas Essential Knowledge and Skills (TEKS) mandated by the TEA curriculum. Based, in part, on the report compiled by the National Academy of Sciences, *Rising the Above the Gathering Storm [2],* the T-STEM initiative aims at producing a better educated and more productive technical workforce.

A significant amount of attention has been paid to improving STEM education; however, we continue to attract only a fraction of the students needed in the workforce and teaching [3]. Moreover, women and minority students have remained disproportionately underrepresented in STEM degrees [3,4].. A key issue contributing to this problem is that

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there is no formal tradition of engineering in K-12 education, few courses in the TEA inventory have substantive engineering content, and certification and degree programs rarely provide teachers and administrators exposure to engineering disciplines or practice, leaving them inadequately prepared to help students make informed educational and career choices regarding engineering. Mathematics and the sciences are necessarily empirical with strict methodologies for rigorous objective inquiry that students have difficulty connecting with as practical skills with relevance in their daily lives. However, engineering projects provide a practical context for STEM concepts to be applied creatively as empowering methods to address relevant human problems [3].

BACKGROUND AND HISTORY

The Texas Tech University T-STEM Center is focusing on integrating project-based, engineering-design into the 6-12 classrooms by training teachers to use engineering design projects as a pedagogical framework to illustrate relevant applications for concepts from the core subject areas in the curriculum----math, science, language arts, and social sciences. Because engineers use math and science in application, this framework gives teachers tools to demonstrate the "why" of learning math and science through logical and realistic problem resolution.

In preparing our proposal to TEA, we examined the Texas Assessment of Knowledge and Skills (TAKS) performance in science and mathematics among all 10th and 11th grade students in Education Service Center (ESC) Region 17, Lubbock, Texas. We also conducted a needs survey distributed through four other Education Service Centers in the west Texas region, which asked high school principals to provide data on courses their students take, and if teachers were teaching out of their disciplines. The survey also incorporated Likert Scale responses for their overall impressions of the quality of the mathematics and science programs in their schools, content knowledge of teachers and students. Other questions asked about engineering content in courses, and what effect they thought engineering projects would have on their student's math and science content knowledge. The survey was emailed by each ESC to principals in their region, and responses were sent directly to us. the results are as follows:

Region 17 TAKS Performance:	Met Standards	Commended	Mastery All Objectives
10th Grade / 11th Grade Science	53.6 / 78.1	7.3 / 4.1	13.3 / 12.4
10th Grade / 11th Grade Math	58.7 / 77.5	8.1 / 13.5	7.9 / 14

Survey Responses (30 respondents):

1. Percentage students taking classes (3482 total in grades 11 & 12) Physics 22%, Pre-Calculus 15%, Calculus 06%, Pre-engineering 01%
2. Are all teachers certified in all disciplines they teach: yes 83% - no 17%
3. Overall Impression of program quality (1 lowest - 5 highest) Math Program 3.55 avg., Science Program 3.53 avg.
4. Overall Impression of content knowledge of teachers (1 lowest - 5 highest) Math Teachers 4.14 avg., Science Teachers 4.13avg.
5. Overall Impression of content knowledge of students (1 lowest - 5 highest) Math 2.98 avg., Science 3.16 avg.
6. Any courses with engineering content: yes 21% - no 79%
7. If students were required to apply math and science in engineering projects, what effect on performance: improve 86% - remain the same 14%.

The TAKS results demonstrate that a significant number of students do not meet the standards for mathematics and science. Principals think their math and science programs are just above average in quality and produce students with just above average knowledge and mastery. They feel their teachers have above average content knowledge in both areas––and with 83% of teachers certified in all disciplines that they teach, West Texas schools are a little better staffed than other areas. The percentage of students taking physics and calculus are a small fraction of 11th and 12th graders. While few schools offer Principles of Technology, most of the principals felt that a project-based engineering course would improve student knowledge in mathematics and science.

Based on extensive previous professional development training of three centers at Texas Tech-----Center for Engineering Outreach (CEO), Howard Hughes Medical Institute/Center for Integration of Science Education Research (HHMI/CISER) and the Outdoor Learning Center (OLC)—the Texas Tech T-STEM Center has experience and credibility to deliver high-quality professional development to Texas teachers in project-based engineering-design.

For over seven years the CEO has been training teachers to use engineering design as a framework for project-based-learning in summer workshops such as with Intro to Rocketry, Advanced Rocketry, Space Science, and Intro and Advanced workshops in robotics using LEGO Mindstorm kits. The success of these programs is exemplified by Estacado High School, a Lubbock high school with an overwhelmingly low-income African American and Hispanic student population with less than 10% of its graduating students entering any post-secondary educational programs, including technical programs, and few if any of their students sought degrees in engineering. Last year all, the first four students graduating from the Pre-college Engineering Academy Program at Estacado went on to higher education and are seeking degrees in engineering. This year all ten students graduating from the program have been accepted into universities, and seven are pursuing engineering degrees. There are approximately 60 students currently enrolled in the program.

The success of this program is due in large part because we have given the teachers of Estacado and its feeder school Dunbar Middle School the tools to engage students in hands-on learning. In fact, for the first time in the history of Estacado, one of its graduates applied to and was accepted to both MIT and Princeton.

At the same time, HHMI/CISER has 12 years of offering professional development in science to Texas teachers by providing pre-service students opportunities to work with the College of Education and with science faculty in teaching and training experiences to enhance their preparation for classroom teaching, provide professional development workshop in biology, and support teachers with the HHMI Traveling Lab program—two vans that travel to schools in rural Texas so that teachers have hands-on resources to use in their classrooms.

The Texas Tech Outdoor Learning Center uses the natural environment as a means to show students and teachers the excitement of learning out side the classroom. Through a Department of Education grant, the OLC was able to purchase equipment such as GPS systems, microscopes, specimen gathering equipment, and measuring tools so that each child attending the OLC will have experience using these tools. The master teachers at the OLC spend time with each school, currently 5th grades, giving the teachers and students pre-OLC training on what to expect when the class attends 5 days and 4 nights at the OLC on the Texas Tech Junction campus. Aligning with the TEKS, students learn through hands-on application that science and math is all around them.

PHASE I: DESIGN

The T-STEM Initiative has awarded funding in two phases—Phase I: Design Phase and Phase II: Implementation Phase. In Design Phase all five T-STEM centers are working out details on how to best deliver STEM professional development to Texas Teachers that will include classroom rigor, active learning, project-based learning and address the state standards (TEKS) while giving them the confidence to try innovative ways of teaching. At the same time, the centers are charged with addressing the Texas Governors Industry Cluster whose objective is to "stimulate long-term sustained growth and focus the allocation of state resources on key industry clusters that economists say will be the engine of job creation and economic development in the 21st century" [6]. In addition, we are charged with building a STEM innovative network and developing a business plan for sustainability.

These three Texas Tech University centers have come together to design the Texas Tech T-STEM Center. Using knowledge and skills from Texas Tech faculty and trainers knowledgeable about teacher training, the Texas Tech T-STEM Center is developing an innovative way to integrate engineering into the classroom. The design of the T-STEM Center depends on the input and ownership of all three centers. Having the Texas Tech T-STEM Center in the Texas Tech Office of the Provost insures that the university is in full support of this center and gives the T-STEM Center access to experienced faculty and resources. However, it is the synergy of the leaders within these three centers that has supported the innovative design of the Texas Tech T-STEM Center. With experience and knowledge that augment each other, the centers' leaders are designing a unique and viable center that address the T-STEM initiative but that also challenges the traditional way of teaching math and science in 6-12. By partnering with five Educational Service Centers (ESC) the Texas Tech T-STEM Center has opportunities to impact a large number of rural schools previously left out of some professional development training.

Because the professional development being developed by the center is rooted in curriculum and pedagogy that has no tradition in K-12 education, we have partnered with BSCS Inc. in Colorado Springs, Colorado, to help in the design, field testing, and assessment of the project-based engineering design curriculum we are developing at the Texas Tech T-STEM Center.

To become a model for using project-based engineering design to affect change in STEM education, goals for the center include:

- Align high school, postsecondary education, and economic development activities across the areas of STEM and the broader high school curriculum.
- Lead the transformation of teaching methods, teacher preparation, and instruction in science, technology, engineering, and math in areas of high need across the state.
- Demonstrate how the implementation of T-STEM teaching and learning increases the number of Texas high school students, from diverse backgrounds, graduating prepared to succeed in postsecondary study and careers in STEM-related fields.
- Train administrators, principals, and teachers in effective leadership strategies for supporting T-STEM instruction in secondary schools.
- Disseminate promising practices and research-based strategies for integrated STEM teaching and learning to all high schools.

To accomplish these goals, the center will evaluate its progress based on the following objectives, and measure its performance on the number of opportunities it provides the teachers and students of Texas:

- Research and guidance
- Teacher training/professional development
- Curriculum
- Tools and resources
- Special events: after school programs/ guest speakers/
- Enterprising model/ongoing and industry support

To accomplish these goals, the center will adhere to the following objectives: The T-STEM Centers will ensure national best practices are utilized in Texas and will identify and document best practices at a local and state level. As programs prove effective, the Centers will broadly disseminate information on T-STEM programs to teachers, schools,

education service centers, district leadership, and other key partners across Texas. The work of the center aims at creating programs and a research-driven pedagogical foundation in STEM education that will be institutionalized

DEVELOPMENT

The development stage of the Texas Tech T-STEM Center consists of assembling the Design Team, and this is probably one of the most critical tasks for the center. Gathering experts in fields that both augment each other but are diverse in knowledge and background is imperative in developing a synergy that will drive creative and innovative ideas for STEM education. The Texas Tech T-STEM Center has gathered together a diverse partnership of institutions and organizations who are interested in bringing about change in 6-12 education in Texas. Among the Texas Tech T-STEM partners, besides BSCS Inc., are five educational service centers from Abilene, Amarillo, Lubbock, Midland and San Angelo; Jeffersonian Institute In Jefferson, Texas, Lubbock Economic Development Association, Science Spectrum Museum, Texas Rural Coalition, Texas Business and Education Coalition, Texas Alliance for Minorities in Engineering, Texas Partnerships in Aero-science Education, and Johnson Controls, Inc, Lubbock Branch. With these partners, input from communities and from industry is helping to design a T-STEM Center that will not only offer training to teachers but address deeper issues of community and family involvement and will help in providing resources and support to teachers. In addition, these partnerships will play a vital role in the implementation of the Professional Development Institute program

IMPLEMENTATION

Using water resources as the theme of the pilot Texas Tech T-Center Professional Development Institute (PDI), the Texas Tech T-STEM Center is designing the pilot engineering-design program that will reflect three different water sheds environments in Texas — the Ogallala aquifer and arid playa lakes of the high plains in the Lubbock region; the spring-fed Llano river watershed in the Texas hill country in and around Junction, and bayous and other unique water shed environments of the Caddo Lake area around Jefferson. Basing the pilot on water resources allows us the opportunity to integrate real-world laboratories in which teachers can see unique ways of integrating resources around them into the classroom. Not only will science and math be involved in the training, but content will also include engineering-design based projects that demonstrate salient issues in water and wastewater treatment, conservation, and recovery.

In a resent article in the *Chronicle of Higher Education*, Domenico Grasso and David Martinelli, addressing issues brought forth in *Rising Above the Gathering Storm*, contend that what the United States needs is not necessarily more engineers but that we need to maintain the quality of engineers we are graduating, and that in the 21st century engineers need to be educated more holistically. In other words, they would like to see engineering students "look beyond the fields of math and science, in search of solutions to entire problems," and that for engineers that we need to be graduating now and in the future, "engineers must at least attempt to understand the human condition in all its complexity—which requires the study of literature, history, philosophy, psychology, religion and economics, among other fields" [7]. The Texas Tech T-STEM Center is addressing these issues by offering training to teachers of all disciplines, and designing courses that will integrate math, science, as well as language arts and social sciences. Eventually, we want cohorts of teachers from each of the disciplines taking the PDI workshops and developing and designing innovative teaching approaches to STEM based on the Texas Tech T-STEM engineering-design model.

SUPPORT

While engineering projects provide a practical context for STEM concepts to be applied creatively as empowering methods to address relevant human problems, teachers typically have very little experience in managing projects effectively. Our training begins by developing a logical model for engineering design by overlaying the unfamiliar structure of the engineering project-lifecycle model, with the familiar five "e" model for instruction. Our project-lifecycle approach is designed to be scalable, so we begin with short duration activities of a few minutes that emphasize the key activities and processes of engineering design, and gradually move them into more detailed, longer duration projects. We employ a heuristic guide that reflects the activities required at each phase of a project. This approach asks a series of questions aimed to elicit a complete consideration of constraints and issues that must be addressed during each phase of the project.

In addition, each phase of the project in our model requires a document or presentation to define the requirements that the next phase of the project must address. We also employ a heuristic approach to this project documentation using a series of prompts that provide a relatively complete first draft that reflects the conventions of various project documents. The project documentation not only provides a means of evaluating the quality of the work being done by the project team, but they also allow the Texas Tech T-STEM Center a means to provide ongoing support to the teachers we train.

During the semester, the teacher can have their students submit their project documents for feedback from center staff or content experts from among our faculty or industry partners. We also provide review panels for critical design reviews that can be conducted on campus, or via video conference to help support the teachers we train. Before students begin building or implementing their designs, they must present the process and defend their design decisions, and predict performance of the design. The panel members ask questions and provide feedback to students, before making their recommendation about anything the students need to address before building the project.

In addition, HHMI/CISER has two mobile labs that travel to rural schools so that teachers have resources in their classrooms that they might not otherwise have, and the Outdoor School has one mobile lab that offers similar support; we are equipping these labs with technological resources that teachers might need to introduce their students to project-based engineering design.

CONCLUSION

Even though the Texas Tech T-STEM Center is less than a year old, we have gathered together a team of participants who can contribute with unique and varied experience in professional development training for K-12 teachers. Using the expertise of the three founding centers—Center for Engineering Outreach, HHMI/CISER, and the Outdoor Learning Center—our T-STEM Center offers numerous years of experience to Texas teachers.

Ongoing formative evaluation of programs and activities, including professional development institutes, will be built into center activities using qualitative and quantitative data collection methods. K-12 teachers, administrators, and students that participate in center activities will have opportunities to provide feedback and evaluate their experience before and after STEM education encounters.

Ongoing self-assessment of programs and activities will be conducted by center management throughout the course of the grant. As activities are completed, directors and staff including the program coordinator and professional development team will debrief to qualitatively gauge the effectiveness and immediate impact of STEM activities. In addition, long-term evaluation of center activities is expected as part of ongoing critical evaluation of the center's progress.

Finally, a contracted, independent evaluator will conduct ongoing assessment of the Texas Tech T-STEM Center's progress based on reports provided by the center's management. The evaluator will also be responsible for comprehensive, six-month reviews of the center's progress and effectiveness which will be delivered as part of the center's interim reports to TEA.

All of the project activities will also have data gathering requirements that will be used to measure the number and kinds of interactions with K-12 teachers, administrators, and students such as participation in training or competitions, or usage of materials and resources available on the Texas Tech T-STEM Internet Portal. Metrics to measure the quality and effectiveness of these interactions will be developed as activities and materials are developed. The overarching goals of the program are to better prepare and increase the number of Texas students entering degree and technical certification programs in STEM fields, particularly from demographic populations currently underrepresented in those areas. Similarly, we hope to increase the number of teachers entering STEM areas, and improve their content knowledge and teaching skills in STEM and specifically in project-based, engineering design.

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