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Preparation and Inspiring Local Middle and High School Student with a Pre-Freshman Engineering Program called PREP.

Abstract

The education of a scientist or an engineer begins long before the student enters an undergraduate program to study their chosen STEM field. Childhood influences and experiences impact which students will academically prepare for and consider pursuing postsecondary education in STEM fields. Many middle and high school students however grow up in a home where their parents do not have a college degree and where their economic situation may discourage pursuing higher education. Supplemental classroom and summer camp experiences that promote STEM play a critical role in many students’ lives in these important transition years. The methods and long term impact of one such program with a twenty-six year track record of attracting and preparing minority students is examined. The Pre-Freshman Engineering Program (PREP) is an educational summer program aimed at Hispanic middle and high school students to increase educational preparedness and interest in STEM fields. The three year academic program that serves middle and high school students interested in STEM runs seven weeks each summer. Courses (Introduction to Engineering, Logic, Computer Science, Algebraic Structures, Introduction to Physics, Problem Solving, Introduction to Probability and Statistics, and Technical Writing) coupled with several engineering design projects/competitions (bottle rockets, solar cars, bridge building, catapults, hovercrafts, and robotics) help students see the relevance of their summer STEM courses. The percentage of students who participate in the program, attend college, and graduate in STEM fields has been tracked throughout the programs history. The success of the program in attracting above average numbers of young men and women to pursue engineering and other STEM fields is presented and related to the program methods. Several key factors influencing the success of the program, which has grown to serve over 350 students per year locally, are identified presented as a model that can be duplicated in an effort to increase the number of graduates in STEM fields.

Introduction

The education of a scientist or an engineer begins long before the student enters an undergraduate program to study their chosen STEM field. Childhood influences and experiences impact which students will academically prepare for and consider pursuing postsecondary education in STEM fields. Experiences and influences that positively affect students at the middle and high school level where academic preparation is critical include the example and influence of parents, teachers, and peers. Hispanic middle and high school students in the South Texas border region often grow up in a home where their parents do not have a college degree and where their economic situation may discourage pursuing higher education. For students in this region, exposure to professional STEM careers will likely need to occur outside the home. Supplemental classroom and summer camp experiences that promote STEM play a critical role in many students’ lives in these important transition years. Increasing the number of graduates in STEM programs in South Texas will require encouraging and preparing underrepresented minority middle and high school students through special programs focused on STEM. One
such program with proven success in attracting and preparing minority students is the Pre-freshman Engineering program (PREP). Nationally, attracting a greater number of students to consider, prepare for, and pursue STEM fields may require new programs such as PREP that challenge, prepare, and motivate young minds.

Pre-Freshman Engineering Program (Longitudinal Data)

The Pre-freshman Engineering Program (PREP) is an educational summer program aimed at Hispanic middle and high school students to promote greater interest in STEM fields and provide significant opportunities for students to be better prepared for pursuing degrees in STEM. PREP was founded in 1979 by a University of Texas at San Antonio mathematics professor, Dr. Manual Berriozabol. The PREP program was replicated at several sites throughout Texas in 1986 (PREP) including three schools along the US-Mexico border; the University of Texas – Pan American in Edinburg, the University of Texas at Brownsville, and Texas A&M International University in Laredo. In 1997, with a grant award from NASA, the PREP program was replicated nationally at Hispanic serving institutions. Currently, there are 35 PREP sites serving minority populations.

Since the inception of the PREP program 29,117 middle and high school students have completed at least one summer component of PREP. Of this group who have been exposed to and better prepared for careers in STEM, 81% have been members of minority groups, 53% have been women, and 38% have come from economically disadvantaged families. The PREP program primarily serves students in the state of Texas where the percentage of 2010 high school graduates who were enrolled in college (2 or 4 year) in the following semester is approximately 56% statewide. For the local school districts served by the PREP program, the college going rate varies from approximately 50% to 80% with an average for all students of approximately 62%. For a three-year recent cohort of all high school students in the area served approximately 18% had earned a bachelorette degree based on a six to eight year window following high school graduation. Based on a 2009 survey of former PREP students who are of college age, 99% are currently attending or have graduated from college. Of the college graduates, 75% are from underrepresented minority groups and 45% majored in STEM fields. In 2010, a total of 4026 students were involved in the seven-week PREP program. The distribution of those students in PREP programs around the state is shown in Table 1. Over the past several years the Edinburg PREP program has been steadily growing (approximately 190 students in 2007, 250 students in 2009, and 347 students in 2010) along with many of the other 35 PREP programs around the state and nation.

The PREP program is a three to four year academic program that runs seven weeks each summer serving middle and high school students. Students take four classes each year including career awareness seminars focused on STEM. Courses include Introduction to Engineering, Logic, Computer Science, Algebraic Structures, Introduction to Physics, Problem Solving, Introduction to Probability and Statistics, and Technical Writing. The curriculum for the first three years of the PREP program is well established and consistent among the 35 PREP sites. A number of PREP sites also offer a fourth year program and a generalized curriculum is currently being developed that will introduce greater depth in engineering topics. The Texas Education Agency
has authorized participating school districts to award elective credit toward high school graduation for each year of the program completed.

Table 1. PREP Enrollment by Site for Summer 2010

<table>
<thead>
<tr>
<th>City</th>
<th>#</th>
<th>Location</th>
<th>City</th>
<th>#</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington</td>
<td>9</td>
<td>University of Texas at Arlington</td>
<td>Harlingen</td>
<td>160</td>
<td>Texas State Technical College</td>
</tr>
<tr>
<td>Arlington</td>
<td>94</td>
<td>Tarrant County College – S.E.</td>
<td>Houston</td>
<td>318</td>
<td>Univ of Houston-Downtown</td>
</tr>
<tr>
<td>Austin</td>
<td>101</td>
<td>Huston-Tillotson</td>
<td>Laredo</td>
<td>247</td>
<td>Texas A&amp;M International University</td>
</tr>
<tr>
<td>Bay City</td>
<td>8</td>
<td>Wharton County Junior College</td>
<td>Laredo</td>
<td></td>
<td>Community College – South</td>
</tr>
<tr>
<td>Brownsville</td>
<td>174</td>
<td>University of Texas at Brownsville</td>
<td>McAllen</td>
<td>90</td>
<td>South Texas College - McAllen</td>
</tr>
<tr>
<td>Corpus Christi</td>
<td>103</td>
<td>Del Mar College</td>
<td>South Texas</td>
<td></td>
<td>South Texas College – Weslaco</td>
</tr>
<tr>
<td>Dallas</td>
<td>425</td>
<td>Brookhaven College</td>
<td>Odessa</td>
<td>235</td>
<td>UT- Permian Basin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cedar Valley College</td>
<td>San Antonio</td>
<td>1385</td>
<td>Northeast Lakeview College</td>
</tr>
<tr>
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<td>Eastfield College</td>
<td></td>
<td></td>
<td>Northwest Vista College</td>
</tr>
<tr>
<td></td>
<td></td>
<td>El Centro College (West Campus)</td>
<td></td>
<td></td>
<td>Palo Alto College</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mountain View College</td>
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<td>St. Phillip’s College</td>
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<td></td>
<td>Richland College</td>
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<td></td>
<td>San Antonio College</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Southern Methodist University</td>
<td></td>
<td></td>
<td>University of the Incarnate Word</td>
</tr>
<tr>
<td></td>
<td></td>
<td>University of North Texas at Dallas</td>
<td></td>
<td></td>
<td>UIW Dual Enrollment Center</td>
</tr>
<tr>
<td></td>
<td></td>
<td>University of Texas at Dallas</td>
<td></td>
<td></td>
<td>St. Mary’s University</td>
</tr>
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<td>Edinburg</td>
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<td></td>
<td></td>
<td>UT- San Antonio - Main Campus</td>
</tr>
<tr>
<td>Fort Worth</td>
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<td>Tarrant County College - South</td>
<td></td>
<td></td>
<td>UT- San Antonio - Downtown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Texas Wesleyan University</td>
<td>Victoria</td>
<td>35</td>
<td>The Victoria College</td>
</tr>
</tbody>
</table>

Students are also involved in many engineering design projects/competitions, throughout the summer including bottle rockets, mousetrap powered cars, model bridge building, miniature catapults, hovercrafts, robotics, and other projects that vary by year and site. Many of the projects are incorporated into the PREP course curriculum so that students see the relevance of their summer STEM courses. The Edinburg PREP program has a yearlong program where students return once a month to the UTPA campus to work on more in-depth engineering projects that culminates with a competition in the summer. During the last summer program, the group built Lego Mindstorm NXT Huminoid robots and Parallax robots powered by a Basic Stamp microcontroller for a summer robotics dance competition and several maze navigation competitions. The competition is a community event where students can involve their families and demonstrate what they have learned.

Elements of Success: Proven Plan, Pedagogy, and Platform

Understanding the causes behind the effectiveness of the PREP program can be difficult. The program effectively operates at many sites across the nation in different demographic regions. The Edinburg PREP site has been directed by several individuals with varying backgrounds and positions and has operated on a campus that has gone through many changes in the past 25 years. There are however four elements that stand out as key elements to the success and effectiveness of the program. The PREP program uses a well-developed curriculum, integrates engineering design projects into the learning process, is offered in a stimulating learning environment, and has enjoyed sustained enthusiastic support.
One of the key elements identified related to the success of the PREP program is the focus on a well developed curriculum. Since the program is voluntary and supported in part by the local school districts the curriculum must interest and engage the students while also producing significant positive learning outcomes. Significant effort has gone into the development of a generalized curriculum that is used at all of the PREP sites to best meet the program goals stated above. The materials and resources are regularly reviewed and revised and sites trained on the use of new curriculum. Practical application is incorporated into the curriculum to provide a greater depth of learning and to better engage and motivate students. While flexibility in the execution of the curriculum among the various sites supports its success with individual teachers and local personalities of student populations, feedback from the sites helps to build a robust and effective learning environment that an individual instructor would struggle to create on their own.

The success of the PREP program in attracting students to STEM disciplines (99% of PREP students attend college) and preparing them for the rigor of those disciplines (45% of PREP college graduates majored in STEM) is due in part to the integration of engineering design projects with classroom learning. Each year students participate in a yearlong engineering design project that culminates in the summer program and in smaller weekly design projects during the seven week summer program. The integration of the projects with the course learning motivates and engages students and helps them see the relevance of the course content as they learn. The projects have been carefully selected and designed to support the program learning objectives. The careful selection and integration of projects to meet specific learning objectives is an aspect of an effective inductive learning pedagogy called Challenge Based Instruction.

A positive and supportive learning environment is essential to effectively accomplishing the learning objectives that the curriculum and pedagogy is intended to support. The ultimate objective of the PREP program is to prepare students for and motivate them toward higher education particularly in STEM fields. The university setting is an ideal environment for the program. Exposure to college students, STEM faculty, campus laboratory and research facilities, college life and recreational facilities, give the students an accurate and positive picture of the opportunities available on a university campus. Guidance is provided by college student mentors who serve as positive role models and by university faculty and area high school teachers who are able to challenge and inspire students in this new and exciting learning environment.

A good educational program cannot be sustained without enthusiastic support. Programs require continued funding from sources that have a sustained interest in the mission of the program. There are many state initiatives, foundations, school districts, and corporations that have an interest in STEM education. These stakeholders provide the needed funding and support for the growing PREP program. The support of the university includes an administrative structure that aligns the mission of the PREP program and its activities with the mission of the university. Becoming a working partner with the university has played a role in its 25 year presence on the campus. The involvement of families, who ultimately make the decision about student participation, effects retention and is a source of support and encouragement regarding future education and career opportunities.
The four key elements, a well developed curriculum, integration of engineering design project, a stimulating learning environment, and sustained enthusiastic support, all work together to provide a program that has significantly impacted STEM education locally and nationally. Although there is overlap between each of these elements they can in part be examined individually. A detailed understanding of each of these elements helps to explain the success of this program and also sheds light on the development of like programs and what will be the key elements to the effectiveness and success of those new programs.

Proven Plan: Well Developed Curriculum

The use of a generalized curriculum with good supporting materials is important for a number of reasons. The approval of TEA elective high school credit is based on the fact that each site is offering the same quality content to students. Since the PREP program is a summer program the teachers are all temporary employees. PREP teachers are a mix of college professors and area high school teachers with varied backgrounds in STEM fields. An established curriculum helps teachers step into the classroom and offer a course that interests students in STEM fields, relates to the design projects, and prepares them for future studies in STEM without having to spend significant time developing course content and materials. The generalized curriculum also serves to ensure that important threads of learning tie the content together for the four year program and that a basic foundation for STEM is built across the courses. The curriculum is regularly reviewed at semiannual PREP directors meetings and training and materials provided for new sites or as changes are made in the curriculum.

The PREP curriculum is designed so that each year builds on foundational concepts needed in STEM fields. Students who only complete the first year still benefit from the program in terms of preparedness for STEM careers. Since continued participation in the program requires successful completion of the previous year’s curriculum, the curriculum is progressive and grows in depth and rigor. The final year serves as a capstone experience for students who are beginning to make important decisions regarding future careers based on their interest and abilities in STEM. The curriculum is designed to give them good exposure to all aspects of STEM including specific career opportunities. The courses offered in each year of the Edinburg PREP program are shown in Table 2.

Table 2. Edinburg PREP Courses by Year

<table>
<thead>
<tr>
<th>PREP Year 1</th>
<th>PREP Year 2</th>
<th>PREP Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic</td>
<td>Algebraic Structures</td>
<td>Probability &amp; Statistics</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>Problem Solving</td>
<td>Problem Solving</td>
</tr>
<tr>
<td>Introduction to Engineering</td>
<td>Physics</td>
<td>Technical Writing</td>
</tr>
<tr>
<td>Computer Science</td>
<td>Seminar</td>
<td>Seminar</td>
</tr>
<tr>
<td>Seminar</td>
<td>Career Awareness</td>
<td>Career Awareness</td>
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<tr>
<td>Career Awareness</td>
<td></td>
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</tr>
</tbody>
</table>

A committee of PREP directors, who understand the program and the needs and interests of students, was recently formed to review and further develop the fourth year curriculum. The curriculum gives students the opportunity to investigate and explore ideas and see the practical
aspects of what they are learning through the integration of relevant projects. A challenge is that
the curriculum must be delivered by teachers without requiring unreasonable training or
expertise and be replicated at all sites without undue equipment costs or facility requirements.

Each course in the curriculum was designed to stimulate interest in STEM fields and to better
prepare students for undergraduate studies in those fields. The courses combine the presentation
of fundamental knowledge with practical application. For example, in the Introduction to
Engineering course first year PREP students are introduced to many of the fundamental
engineering concepts that might be introduced in an undergraduate introductory course but with
a greater emphasis placed on application. Because the PREP program is supplementary to their
formal educational setting, a greater emphasis can be placed on the depth of learning and
application in key areas that impact and motivate students.

The Introduction to Engineering course curriculum illustrates the mix of fundamental concepts
with practical application. In this course students learn about tension and compression and the
design of simple trusses. Then they are shown how to design trusses using a bridge building
program and finally apply that skill in a bridge building competition. As part of the course,
students also work through a three week module on digital signal processing (DSP). After
learning the basic concepts they use LabView to understand and experiment with echo, signal
encoding, and noise cancellation. The curriculum is designed so that all students can get through
the basic material but additional resources are provided to keep students interested and focused.
The required assignments for the DSP project (Programs 1-10 and 20-23) are shown in Figure 1.
Students who want to explore programming further or who move quickly through the content
experiment with other DSP programs or follow the online tutorials to create their own
applications. As a final practical application for the DSP module they design, construct, and test
their own moving-coil loudspeakers.

![DSP Course Content and Additional Resources](image-url)

Figure 1. DSP Course Content and Additional Resources.
Proven Pedagogy: Integrating Projects with Learning (Challenge Based Instruction)

The effectiveness of integrating engineering design projects into the curriculum cannot be overlooked while evaluating the success of the PREP program. Although the PREP projects used throughout the curriculum have been developed by several individuals with differing pedagogical interpretations, the pedagogical method of inductive learning called Challenge Based Instruction (CBI)\textsuperscript{1,2} might well explain the use of projects in PREP. This learning method has been widely used and assessed locally\textsuperscript{3} and nationally\textsuperscript{4}. This teaching/learning method engages the student in the learning process and helps them to better understand the relevance of the instruction and learning objectives while they are learning the course content rather than as the final step of the learning process. The projects are carefully selected to best support the learning objectives of the course. Although the student has the freedom to explore, a carefully selected project keeps them on target with the desired learning outcomes. One of the benefits of CBI is that it takes full advantage of what students already know and stimulates interest in the course content. This method gives students more of an active role in the learning process which in turn makes them more engaged. Engagement and motivation is critical for students who are still exploring where their interests and abilities lie. Students want to be challenged by problems that they understand are relevant in the world they live in. Science and engineering CBI projects will help students see the relevance of what they are learning and start them thinking about the application of STEM knowledge in possible careers.

During the seven week PREP program students are assigned to small groups and assigned weekly engineering design projects beginning the first week. Although the projects may be more suited to the content of one course over another, the instructors of each course are encouraged to integrate the project into their lessons. At the Edinburg PREP site, students also participate in a longer term project called the “mega project”. During the previous two summers students built and raced manned hovercrafts and built different robots for several maze competitions and a humanoid robot dance competition as shown in Figure 2. Students work on these projects throughout the year during monthly meetings and then more intensely during the seven week summer program. At the beginning of the year the projects appear to be unattainable to the students but as they develop the required skills in meetings throughout the year they begin the summer with greater confidence and an interest in continued learning.

To facilitate the project integration with the courses project sub-tasks are given that connect to specific skills learned in various courses. These include requiring students to submit a short design report that explains the thinking behind their design. If a first year student is designing a two liter bottle rocket they might be required to plot the trajectory for different launch angles which their Computer Science instructor would be able to help them with. After a day of testing various designs and collecting data their Logic and Problem Solving instructors may help them map out which are the most advantageous features to the design based on their data. Students are required to make engineering design sketches before they can construct a model which is a task that is supported by their Introduction to Engineering instructor. By the end of the week, students see how their instructors and the knowledge that they have shared in class are a valuable resource that helps them accomplish their goal of winning the competition.
Weekly projects are repeated each year giving the students an opportunity to revisit and refine their designs and relate the project to a new set of courses. A review of undergraduate engineering projects states that “These projects, which build in complexity as they are reintroduced in appropriate classes, help students develop a holistic approach to mastering their discipline.”

To deepen the connection between projects and various courses, the instructors participate as judges in the week’s end competition and provide further support and encouragement to the students in their respective content areas. The instructors are encouraged by this interaction as they see their instruction take form in the lives of the students. Other weekly projects include mousetrap powered cars, popsicle stick bridges, miniature catapults, tetrahedral kites, and egg drop devices.

**Proven Platform: Stimulating Learning Environment**

The learning environment is an important parameter to consider in developing a STEM program for middle and high school students. A college or university setting has many advantages. To young students the college campus represents the next level of independence. Although students are drawn to the university environment for the independence and maturity it represents, it is an appropriate setting to teach that it also represents privilege and responsibility. First generation college students who may at first be intimidated by the campus setting become confident in this new environment. The university environment also exposes students to STEM programs through
campus tours and interactions with college students and faculty that they may not have otherwise considered.

The university setting makes it easier to find STEM faculty who teach the PREP summer courses. The PREP teachers are a mix of certified high school teachers and university faculty. The high school teachers relate well with the students and have a good sense of their capabilities while the university faculty often stretch the students and give them a taste of the rigor of higher education, especially in STEM fields. Many of staff members are former PREP students who have benefited from the program and understand the needs and interests of the PREP students. All of the program mentors in the Edinburg PREP program are college students. These college students each mentor a group of twenty PREP students. They attend classes with the students, help them with assignments in their study period, and assist them with their projects. Using college students as mentors gives the PREP students the opportunity to get to know a college student and catch their vision for learning and pursuing higher education.

Integrated with the second year PREP program is a one week residential engineering summer camp program called PREP Plus. This program offers a morning short-course in vehicle dynamics taught by a university professor. The experience exposes the students to campus life and makes them more comfortable with the campus setting. The program is a highlight for PREP students, gives them greater exposure to engineering, and is the impetus for the development of close relationships among the students which has helped with third year retention as shown in Table 3. Of the 140 students who completed the first year of TexPREP (PREP 1) in summer 2011, 133 have applied for the second year of TexPREP (PREP 2) in summer 2012 and will be the target group from which students will be recruited for PREP Plus+. This target group is 36% female, and 95% Hispanic, which will ensure that both of these under-represented groups in STEM fields will be highly represented in PREP Plus+. The mentors for the PREP Plus+ program are local college students who closely interact with the students in learning activities and in dialog about motivation and success.

<table>
<thead>
<tr>
<th>Participants</th>
<th>2008 to 2009</th>
<th>2009 to 2010</th>
<th>2010 to 2011</th>
<th>2011 to 2012 (projected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREP Plus+</td>
<td>67%</td>
<td>71%</td>
<td>88%</td>
<td>90%</td>
</tr>
<tr>
<td>Non-PREP Plus+</td>
<td>0%</td>
<td>47%</td>
<td>73%</td>
<td>78%</td>
</tr>
</tbody>
</table>

**Proven Platform: Sustained Enthusiastic Support**

The PREP program would not be possible without the strong support of the university. Access to class rooms, engineering and computer laboratories, campus housing, and recreational facilities greatly reduces the costs of the program, makes the students feel welcomed and valued as future university students. The direct costs of the program are met through a variety of sources. State grants have played a major role in encouraging initial growth and development of the program and continue to provide regular support. Sponsorship from foundations and industry that have an interest in promoting STEM education provide additional support for the program.
The local school districts provide significant financial support, provide transportation over a 25 mile radius, and help to promote the program in their schools. A yearly counselor’s meeting with representatives from each of the area districts helps to update counselors on the program. The counselors play a crucial role in identifying and encouraging students from their schools who would benefit from the program.

The university has developed an administrative support structure for outreach programs such as PREP. The directors for each of eight outreach programs at the university make up the Department of College Access and Support Programs which functions under the direction of the Division of Enrollment and Student Services. This structure gives the outreach programs recognition as important contributing members to the mission of the university. Additionally, there is opportunity for coordinated support in transitioning students through appropriate preparatory programs and ultimately to enrollment and support in STEM higher education programs.

The continued support of the community is an essential element to the success of the program. As the program participants are all minors, the parents of participating students make the final decision about enrollment in the program. Providing parents detailed information about the program, including them in orientations and graduation events, giving them easy access to staff when they have questions are a few elements that support positive interactions with families. A community/parents day event has been incorporated into the program to give students an opportunity to demonstrate what they have been learning over the summer. This well attended event, centered on the yearlong engineering design competition, has included the design competition, a lunch served by program staff, interactions between mentors and parents, and tours of the campus and engineering labs. The positive interaction with families has led to the future participation of siblings, extended family members, and even members of the next generation.

Conclusions

The Pre-Freshman Engineering Program has a proven record of success in motivating middle and high school students toward STEM fields. Once motivated, the students are better prepared for those fields over their three to four year involvement in the program as evidenced by their future success as college graduates in STEM fields. The success of the program has been related to a well developed curriculum, the integration of engineering design projects into the learning process, a stimulating learning environment, and sustained enthusiastic support. Although these four key elements are interrelated, a careful examination of each in the context of a successful program has provided evidence that these elements should likely be part of any successful STEM education program targeting middle and high school students.

Bibliography


