AC 2011-1643: THE IPT PROGRAM AT UAHUNTSVILLE AN INNOVATIVE APPROACH TO DESIGN EDUCATION AND STEM OUTREACH

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The IPT Program at UAHuntsville: An Innovative Approach to Design Education and STEM Outreach

Abstract

This paper will review the Integrated Product Team (IPT) program at The University of Alabama in Huntsville. The core of the IPT program is a multi-disciplinary, multi-university senior design experience. This design experience involves students from engineering and non-engineering departments at UAHuntsville as well as engineering and science students from four U.S. universities and two European universities. This year the program has been expanded to include eight area high schools as part of a new outreach initiative called the Innovative Student Project for Increased Recruitment of Engineering and Science Students (InSPIRESS). The goal of the this initiative is to expand the UAHuntsville Integrated Product Team (IPT) program into area high schools in order to help them develop a better understanding of the purpose of science and mathematics education by providing the opportunity to design a payload for a spacecraft designed by the UAHuntsville senior design experience. This initiative exposes high school students to the systems engineering design and integration process over the course of the academic year. This year over 250 high school and college students are involved in the IPT program. The overarching goal of the program is to provide a broad impact across the spectrum of the educational system by establishing the foundation for a highly integrated design program that links undergraduate education and high school education. All of the participants (i.e., faculty advisors, undergraduate students, high school students, and high school teachers) gain experience in the design of a large scale system and a better understanding of the role of various disciplines in that process. A parallel goal is to encourage more high school students to pursue careers in STEM (Science, Technology, Engineering, and Mathematics) related fields.

Introduction

The demand for STEM related careers is projected to be strong well into the second and third decade of the 21st century. In a story dated December 22, 2008 the Mobile Press-Register noted that the Alabama Office of Work Force Development projected that the "state needs to turn out more than 1,100 new engineers a year" for the next decade to meet growing demand[1]. This increased demand for engineers has intensified the need to attract more students into Engineering programs across the state. Also, in 2009 the National Academy of Engineering and the National Research Council released a report which described several general principles for K-12 Engineering Education[2]. Principle one of the report states that K-12 engineering education should emphasize engineering design since it is a potentially useful pedagogical strategy. Engineering design, as described in the report, is highly iterative; provides the opportunity to illustrate that problems can be solved with multiple different solutions; provides a meaningful context for science and mathematical principles, and allows for the inclusion of systems thinking, modeling, and analysis.

Both of these reports provide an increased motivation for universities to intensify their outreach activities in order to entice more students into STEM related careers. As a result The University of Alabama in Huntsville (UAHuntsville) has expanded an existing senior design experience to include a wider variety of constituents and to engage with area high school student in order to

encourage more of them to pursue engineering careers. This paper will review this outreach initiative, the Innovative Student Project for Increased Recruitment of Engineering and Science Students (InSPIRESS).

Integrated Product Team Program

The InSPIRESS initiative is an outgrowth of the UAHuntsville Integrated Product Team (IPT) program which encompasses the undergraduate senior design experience for the departments of Mechanical and Aerospace Engineering and Industrial and Systems Engineering and Engineering Management. The overall mission of the program is to teach students how to translate stakeholder needs and requirements into viable engineering solutions via a distributed integrated product design environment. As shown in Figure 1, the IPT program is creating a STEM pipeline by having undergraduate senior engineering students working together with high school students on an engineering design project. The program is based on the canons of Aristotelian rhetoric whereby you "tell them what you are going to tell them" (InSPIRESS), "tell them" (undergraduate science and engineering curriculum), "tell them what you told them" (senior design experience). As a result the InSPIRESS initiative seeks to communicate a context and purpose to high school students whereby, they can better understand the purpose of the coursework in their freshmen and sophomore of undergraduate engineering education. It also helps them develop a better understanding of the application of the theories they learn in their earlier college years to their discipline specific coursework in their junior and senior years of college.

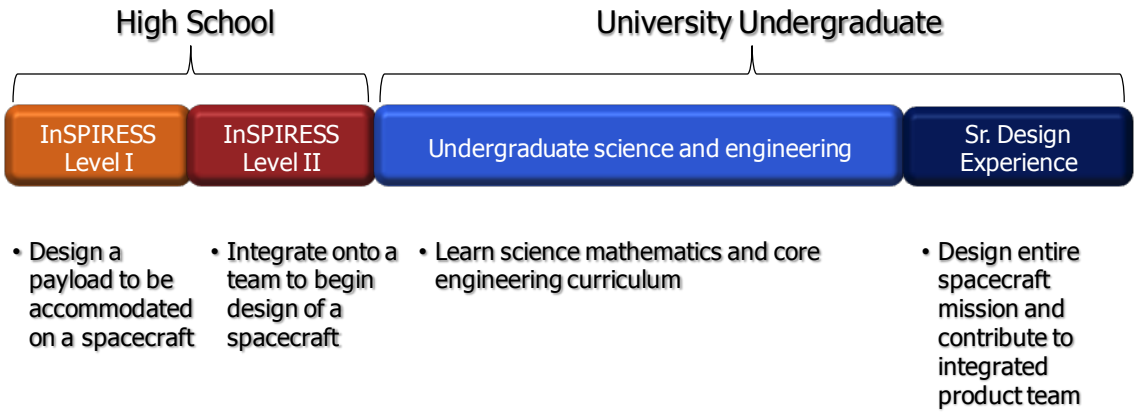

Figure 1 The IPT Program Strategic Mission

The Senior Design Experience

For the past 18 years the capstone course at the undergraduate level in the department of Mechanical and Aerospace Engineering (MAE) was a one-semester long senior design experience. This design experience has been taught in an integrated product team environment with projects that have been supported by the local aerospace community (i.e., NASA or DoD) including involvement from other disciplines such as Electrical Engineering, Marketing, and Technical Communications. The UAHuntsville Senior Design Experience takes a project based learning approach. Project based learning has been viewed, over the last decade or more, as an effective way of teaching design and teamwork.[3,4,5,] The projects have ranged from a concept for

a magnetic levitation train to a concept for a micro unmanned air vehicle to a concept for a segmented solid rocket. The senior design experience endeavored to make the class a microcosm of the real world by emphasizing systems thinking skills, communication skills, and teamwork as well as engineering design and integration. At the beginning of each semester, each of the integrated product teams develops a concept description document (CDD), which contains the design requirements, figures of merit, design constraints, and objectives for that semester's design project. The course instructors help the teams develop a system-level perspective for translating the design requirements into feasible solutions. Each team is divided into project-specific disciplines; for example for a recent lunar lander project, each team had a project manager, systems engineer, communications lead, concept of operations lead, guidance navigation and control lead, power lead, thermal lead, structures lead, and mobility lead. Because of the nature of the project, each student quickly learns that they cannot operate/design in a vacuum – they must interact with every other subsystem lead on their team and approach the design from a system-level perspective. Through this process, the students acquire the basic character qualities that enable them to function effectively in a teaming environment. In 2010 the course was expanded to two semesters and the Industrial and Systems Engineering and Engineering Management department made the decision to integrate their two-semester senior design sequence into the IPT program.

In the IPT program the teams are given open-ended design problems, where there is not a single clear-cut solution, which allows them to practice the critical thinking skills required for success in a changing environment. The instructors have discovered that undergraduate students are generally not accustomed to open-ended problems – in many of their classes they are given problems with definite "right/wrong" answers. With open-ended projects, the senior design experience forces the students outside their comfort zone, where they must sometimes make assumptions in order to move to the next step in the design process. The instructors and discipline mentors guide the students through this process – the UAHuntsville College of Engineering believes it is better for the students to be exposed to this process and to make mistakes in a classroom environment rather than at their first job.

In an effort to expose the students to a world larger than the classroom, the UAH senior design experience has an external review board which participates in each of the design reviews by offering criticism, advice, and expert opinions, and by ranking each of the teams at each step in the process. The members of the review board include: the IPT customer, who works with the instructor and students to define the concept description document (CDD); industrial partners, who are subject-matter experts employed by private companies; and civil service partners, who are also subject-matter experts and typically employed by NASA, the Department of Defense (DoD), or local aerospace and defense contractors. The IPT customer and the course instructors work together to populate the review board and to find technical mentors who offer expertise and advice to the students during the design process. For the 2010-11 academic year the teams are using NASA's Science Mission Directorate's Discovery Program Announcement of Opportunity (Discovery AO) as their guide in the development of their mission concept and proposal for the review board. The purpose of following the Discovery AO was to provide a realistic framework for mission and system development. There are two missions for the 2010-11 academic year: 1) a Radio Astronomy on the Moon (RAM) mission, which seeks to place one or more arrays of radio telescopes on the far side of the Moon, and (2) a Europa exploration mission, which seeks to map and determine the existence of life on Europa.

In addition to the UAHuntsville multi-disciplinary teams and the external review board the senior design experience also incorporates groups beyond UAHuntsville. The class involves five external universities and two other departments at UAHuntsville, as shown in Figure 2. The UAHuntsville senior design experience typically involves at least three partner universities: (1) The College of Charleston in Charleston South Carolina (i.e., U.S. Science Partner); (2) Southern University and A&M College in Baton Rouge, Louisiana (i.e., U.S. Engineering Partner); and (3) Ecole Supérieure des Techniques Aéronautiques et de Construction Automobile, or ESTACA University in Paris, France (i.e., International Engineering Partner). Each of the university partners plays a role in the proposal development process in response to the Discovery AO. For spring 2010 the College of Charleston students served as the Science Definition Team, while the U.S. and International Engineering Partners (i.e., Southern University and ESTACA) received a portion of the system to design and integrate with their UAHuntsville IPT. The portion of the system each of the supporting groups is responsible for is mutually agreed upon by both partners and defined within the Interface Control Document (ICD). The IPT students located at UAHuntsville have the prime responsibility for developing the integrated system with their partners' contributions, thus requiring frequent communication of design requirements and design concept changes. These partners offer the integrated product teams unique experiences, for example: (1) with Southern University, the IPTs learn to work with remote-partners who are in the same time zone and speak the same language; however, (2) with ESTACA University, the IPTs learn to work with remote-partners who are separated by a large time difference, a different culture, and a foreign language. Beginning with fall 2010 two more U.S. Engineering Partners and an additional International Partner were added with California State University – Los Angeles, Alabama A&M University, and Aachen University in Germany joining the program. The new partner's roles are similar to those of Southern University and ESTACA. The College of Charleston continues to serve in the role of the Science Definition Team.

Figure 2 The Senior Design Experience Organization

InSPIRESS Initiative

In spring semester 2010 a pilot program was initiated to bring high school students from two local high schools into the IPT program. That semester, 27 students from Austin and Decatur high schools in Decatur, Alabama were tasked to designing science payloads to be integrated into the spacecraft being developed by the IPT students that semester. The pilot program was very successful – the students, teachers, and administrators who participated were very excited. Anecdotally, the program impacted the future studies of several of the participants. In one instance prior to initiation of the pilot program several of the students were not planning to take AP science or math courses in their senior year. As a result of their involvement with the

UAHuntsville IPT program they all changed their mind and enrolled in AP Science and/or Math courses their senior year. They also asked for more opportunities like the IPT program. The enthusiasm, engagement, and impact of the pilot program caused the course instructors to seriously consider developing a high school outreach component to the UAHuntsville IPT Program. Thus the InSPIRESS initiative was created. InSPIRESS is in some ways an extension of the freshman level design experiences that many engineering colleges have implemented over the last 20 years.[5,7,8,9,10] The purpose of these classes is to help the participants better understand what engineers do. InSPIRESS seeks to do this during the high school years so that students gain a better understanding of engineering before they enter college.

As conceived this year, the InSPIRESS initiative has two levels. Participants in InSPIRESS Level 1 are again focused on the development of a science payload to be integrated into the spacecraft designed by the students in the UAHuntsville Senior Design experience. Participants in InSPIRESS Level 2 are high school seniors who are required to complete an engineering internship as part of their engineering courses – these students are being integrated more thoroughly into the UAH IPT program, with many high school students actually coming on campus to work with the college seniors. The Level 2 program was developed explicitly for the 15 seniors from Austin and Decatur high schools who participated in the pilot program last year (which was the model for the Level 1 program). Participants in the Level 2 program are treated like the Engineering Partners in the Senior Design Experience and are therefore focused on developing an element of the spacecraft. In addition, 12 seniors from Sparkman high school were also invited to participate in the Level 2 program.

At the start of the 2010-11 academic year ten area high schools were approached about participating in Level 1 of the InSPIRESS initiative. The ten high schools were chosen because of their participation in the Engineering Academy Initiative for Alabama (EAIA). The EAIA is a program started five years ago by The University of Alabama System and Auburn University to establish a pre-engineering curriculum in high schools across the state in an effort to attract more students into engineering and to better prepare them for studying Engineering in college. There are currently 25 Engineering Academies in the state with 10 of them located in the North Alabama region. UAHuntsville and Alabama A&M are the sponsors for the North Alabama high schools with Engineering Academies therefore it was logical to start with these schools. It should also be noted that Austin and Decatur high schools which piloted the program last year both have Engineering Academies. Of the ten schools that were approached eight felt they were ready to participate while the other two have newer programs and felt they would be in a better position to participate in 2011-12. For this year there are approximately 118 students in InSPIRESS Level 1 and 27 students in InSPIRESS Level 2.

Figure 3 shows the breakdown of the teams between the RAM and Europa missions. Each mission involves three UAHuntsville teams (i.e. A, B, C for RAM and H, I, J for Europa) that are competing to be selected, by the external review board, as the best proposal. Each of the teams works with a separate Science Definition Team from the College of Charleston, a team from their U.S. Engineering Partner, and a team from the International Engineering Partner. In addition, each of the teams is working with two InSPIRESS Level 1 teams and one InSPIRESS Level 2 team (except for team H). The Level 1 participants are the first two listings under each of

the IPT teams and the Level 2 participants are the listings on the right under each IPT with the exception of team H which does not have a Level 2 team.

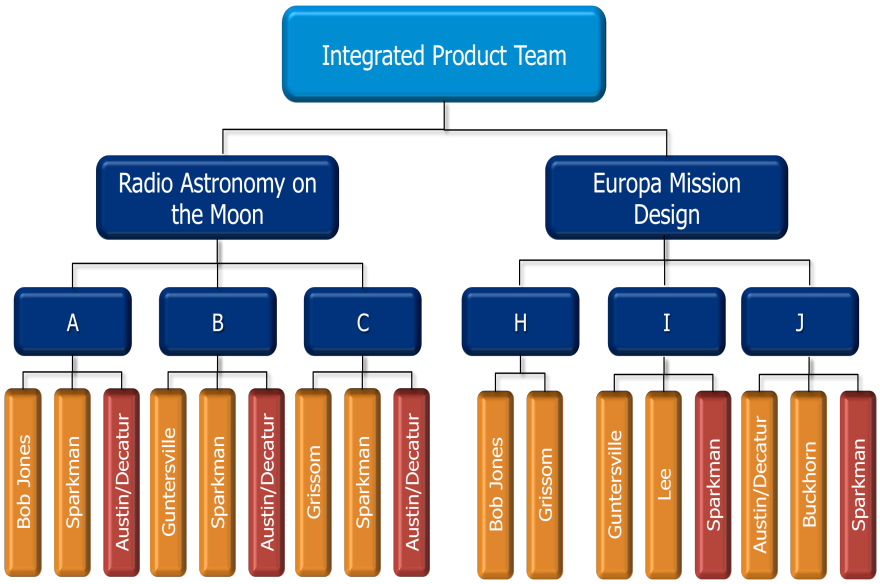

Figure 3 IPT Program Missions and InSPIRESS Participants

As mentioned earlier the goal of the InSPIRESS initiative is the expand the UAHuntsville Integrated Product Team (IPT) program into area high schools in order to provide them with an understanding of the purpose of science and mathematics by providing the opportunity to develop and design a payload for a spacecraft designed by the UAHuntsville Senior Design Experience. This initiative exposes high school students to the systems engineering design and integration process over the academic year as shown in Figure 4. The initiative is divided into three phases. Phase 1 (blue) is the requirements development phase where students learn the importance of the end-user's need for a system. Key aspects of this phase include the development of experiment requirements, allocation of resources, and research into scientific needs. This phase culminates in the development of an Interface Control Document (ICD) negotiated between the high school team and the UAHuntsville IPT team and signed by both parties.

Phase 2 (brown) is the alternative solution phase which lasts approximately two months. This phase provides an opportunity for the students to learn that several solutions exist to solve a problem, however one must be chosen that optimizes the design solution space (performance, cost, schedule, and risk). Key aspects of this phase include the development of a functional flow of the payload, proposed alternative solutions, decision techniques, and the development of a concept of operations which will be the basis of the proposed design. This phase culminates in a preliminary design review with an external review board to assess the performance of each high school team.

Phase 3 (green) is the detailed design phase of the project. During this phase the high school team provides a detailed design of their selected concept (from Phase 2), prototypes the concept, and learns about verification and testing to meet design requirements. This phase culminates in a critical design review with an external review board.

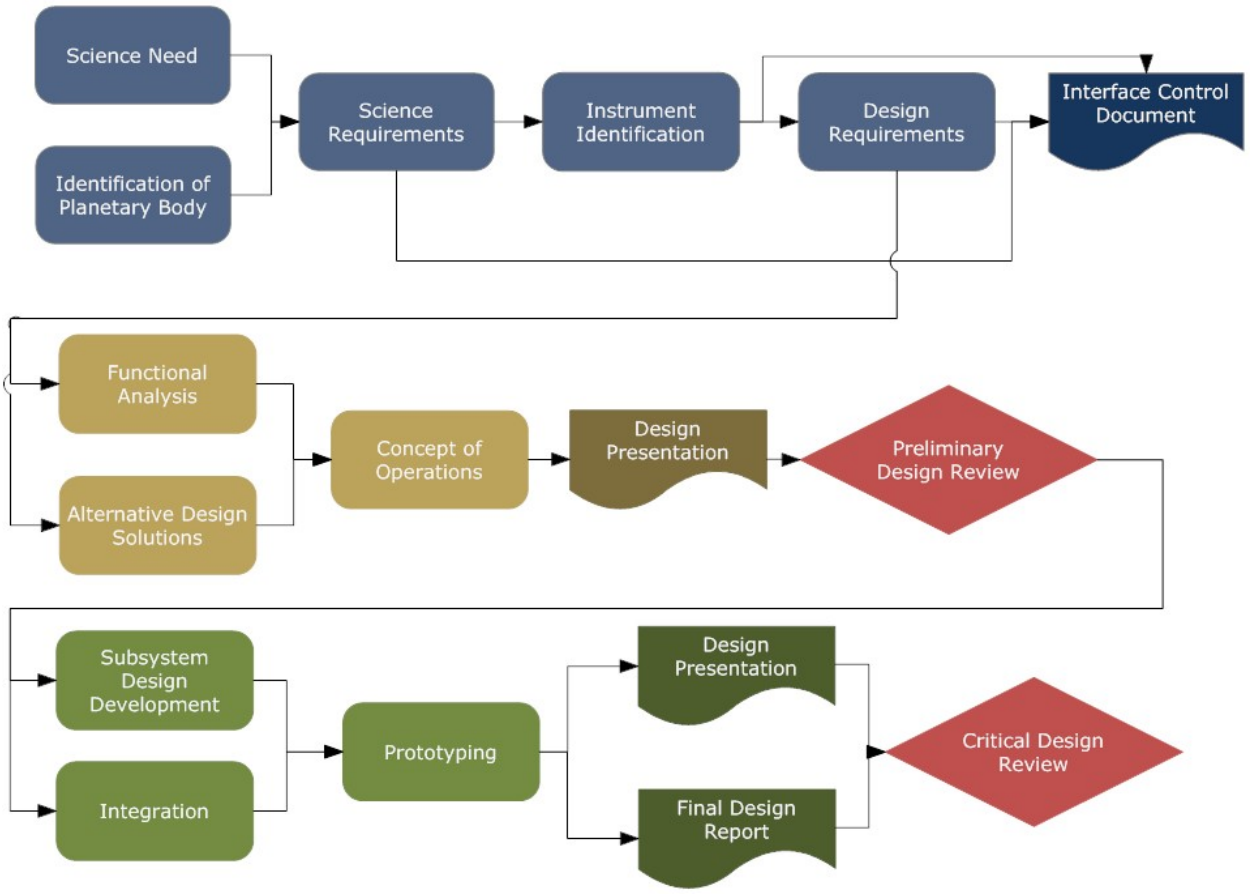

Figure 4 The InSPIRESS Level I Design Process

While the goal of the InSPIRESS initiative is to show a purpose for science and mathematics, it also provides the opportunity for the high school students to begin to learn the importance of key principles of engineering design and integration not directly related to science and mathematics. Specifically this initiative provides an opportunity to learn about teamwork, communication, and marketing - three key skills that future engineers and scientists need to become successful in their professional careers. The high school teams are being challenged to become a cohesive unit to develop their experiment as well as to provide documentation and presentations that communicate their design solution. Throughout the two academic semesters, several opportunities to teach and improve these skills through project based learning will be available. Each high school will be required to present a briefing on their design to a minimum of two middle schools. They will also hone their presentation skills during the design reviews with the external review board and at the community-wide open house on the campus of UAHuntsville at the end of the spring semester.

Outcomes and Benefits

There are many positive outcomes and benefits of the UAHuntsville IPT Program. First and foremost is giving students the opportunity to utilize their engineering skills in addressing a realistic design program. Second, the program helps to transition graduating engineers from student engineers to working engineers. Third, it provides a highly integrated educational

experience that engages students from across the country and world in working together on a compelling design problem. And finally, it is reaching out to high school students interested in engineering careers and helping them develop a better understanding of the role of scientists and engineers.

Overall for the 2010-11 academic year the UAHuntsville IPT program Senior Design Experience will engage over 130 college students and similarly over 130 high school students in the InSPIRESS Level 1 and 2 programs. Within the Senior Design Experience 71% of the participants are male, 29% are female, and 6% are from under-represented ethnic groups. Within the InSPIRESS initiative there are significant levels of participation among females and under-represented groups. Overall, 30% of the InSPIRESS participants are female and 25% are from under-represented ethnic groups. Even more intriguing is the composition of the leaders of the high school teams which are heavily slanted towards under-represented groups – of the 12 project managers for the high school teams only 2 are males the other 10 are females particularly noteworthy since the project managers are elected by their teams not appointed by the teachers. We hope to interview the teachers and students to better understand this phenomenon.

Given that several aspects of the program are being piloted this year a formal metric collection process is just now being setup. At present most of the data available is observational and anecdotal. The following section presents some of those observations. In the InSPIRESS mid-year survey feedback from the high school teachers was very positive about the program. When asked about the level of engagement of their students one teacher commented "Absolutely. I think they have been very engaged and they have learned that they can do things that may seem out of our reach." Another teacher said, "I think it helps them too, to see that the math they are doing in class is the same math used to design things that go out into space." Also, in meeting with the high school students the instructors have observed an increased level of student engagement over time. Students that started the year sitting in the back and not talking are now taking a more active part in the class and even leading discussions. Another interesting observation by the high school teachers is that students are talking about the project in other classes (i.e., Physics, English, etc.) in fact in one case the one of the Physics teachers attended sessions of the engineering class to learn more about the project. Several students have also indicated that the InSPIRESS initiative has them thinking about pursuing engineering as a career something they were not planning to do prior to this year.

The Senior Design Experience has also had an impact on student perceptions and career preparation. More than one student has commented that this class was the first time that they felt like a "real engineer." Also, several students have talked about this project and their role in the class during job interviews and reported back that the interviewers were very impressed. Area employers (i.e., Boeing, NASA, etc.) have actively recruited graduates of the IPT program because of the background they develop in the IPT Program. The industry representatives have also commented on the quality of the proposals and presentations. In particular they like the interaction between the science students from the College of Charleston and the engineering students from UAHuntsville.

Conclusions

Overall, the UAHuntsville IPT Program has garnered much excitement and interest on all fronts. The college students find the missions to be exciting and interesting. Alumni indicate that the team based focus of the course helps them to be better prepared for their jobs after they leave school. They also indicate that potential employers have been intrigued by the projects when they have described the experience during their job interviews. Feedback from employers indicates that the students coming through the IPT Program are well prepared for dealing with similar types of proposals and processes. In fact two area employers have been so impressed with the Program that they have provided gifts to cover the cost of the annual Open House and Banquet as well as providing personnel to serve as mentors for the teams.

Feedback from the high school teachers indicates that the students are excited and engaged in the project. Anecdotal evidence indicates that the students are talking about the project and their design work in other classes (i.e., math and science) to a degree that the teachers of these other classes have noticed and been intrigued (positively) by the change. In fact, one of the science teachers has come to the engineering class to observe the student interactions to gain a better understanding of the project. The success and enthusiasm generated by the InSPIRESS initiative has encouraged the authors to expand the program for the 2011-12 academic year.

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