AC 2011-698: EFFECTIVENESS OF TEAM-BASED STEM PROJECT LEARNING TO RECRUIT MINORITY HIGH SCHOOL STUDENTS TO STEM

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Mr. Oppliger is a professional engineer and a lecturer in the Engineering Fundamentals department at Michigan Technological University. He is the director of the High School Enterprise program which has a mission to increase the numbers of students pursuing post-secondary degrees and careers in STEM fields. At its core, this program supports K-12 teachers who are leading teams of students in long-term STEM projects. This work is the latest in Oppliger's history of working in K-12 STEM areas. For the past 10 years he has developed and taught first-year engineering courses at the University and actively worked with high school students and teachers to increase and enhance engineering content in K-12 education. This includes consulting on K-12 engineering curriculum development for the State of Michigan. In 2004 Mr. Oppliger was awarded the Distinguished Faculty Award for Service honoring this outreach work. He has presented papers at several national conferences on engineering education. Before coming to Michigan Tech, Mr. Oppliger taught math and science at the secondary level for 11 years. Before that, he worked for 5 years as a project engineer in the marine construction industry.

Effectiveness of Team-Based STEM Project Learning to Recruit Minority High School Students to STEM

Abstract

Many high school students have the opportunity to participate in team-based, collaborative STEM (science, technology, engineering, and math) projects during the regular school day or as extracurricular activities. These types of projects have the potential to motivate and help prepare students to pursue post-secondary STEM study, but there is a lack of data to establish what aspects of this type of project work are key in recruiting students to STEM studies in college. This paper examines a program that supports secondary teachers who advise teams of high school students in long-term, team-based STEM projects. The program is now in Year 4 of a five-year pilot and has grown to seventeen teams in three states and Puerto Rico, after starting with an initial implementation in three Michigan schools. The latter years of the program, and the study itself, have been supported by grants from the National Science Foundation. The program relies on partnerships between academia, industry, and the team communities. Assessment of the program includes pre- and post-treatment surveys on attitude toward STEM and perceived skills for teachers and students, examination of teacher education methodology, site visits, and other observational reporting. Initial results reveal aspects of learning in this program that may be important in motivating secondary students to pursue STEM majors and STEM careers. This program has implications for population groups that are underrepresented in STEM as the teams include minority students and women in significantly greater proportions than exist in STEM majors. In AY2009-10, of the 170 or so student participants spread among 12 teams, 38% were female and 39% were minority students. These percentages are between two and four times that of corresponding participation rates in higher education STEM programs. Mid-program results are summarized, including examples of student teamwork, and recommendations for program adaptation and program scale-up are discussed.

Introduction

High School Enterprise (HSE) is a program that engages students from grades 9-12 in active, applied STEM (science, technology, engineering, and math) learning. In an HSE implementation, a team of secondary students (roughly six to twenty per team) that is associated with a secondary school and partnered with a local university works on a long-term STEM project. Each team of students is coached by a high school STEM teacher who has been instructed through university summer workshops on the fundamental aspects of engineering design, project management, teamwork, and entrepreneurialism. Coach support continues during the academic year with biweekly on-line meetings hosted by the university's program director and attended by all teacher-coaches. This inexpensive forum offers frequent networking opportunities among the teachers (peer support) and a regularly scheduled direct link to university program managers (programmatic support). Most instances of HSE function as afterschool programs, and teacher-coaches are paid for their coaching and mentorship just as those who direct afterschool athletics. Students on HSE teams work on projects that are selected by the coach and team and that have local significance for the students and their community.

These projects can continue from one academic year to the next. In the course of their HSE experience, the students write business plans, solve real-world problems, perform testing and analyses, build prototypes, manufacture parts, stay within budgets, and manage their own projects. Each spring, secondary HSE teams showcase their work alongside college students at an undergraduate Expo held on the campus of the partnering university. HSE teams also have access to real-world expertise and mentoring from professionals in academia and industry. It is hoped that, at the conclusion of their HSE experiences, the students will demonstrate proficiency in applied workforce skills, be more disposed to enter STEM careers, and be prepared to undertake the training and education needed for those careers. In short, the goal of High School Enterprise is to motivate and prepare students to pursue post-secondary STEM education and STEM careers.

HSE builds on a small pilot program that Michigan Technological University funded and ran within three Michigan high schools during AY2007-08. Under NSF support (EEC-0835670) in the following year (AY2008-09), the HSE pilot was expanded to five high schools and, in AY 2009-10, to twelve schools with additional support from NSF (DRL – 0833542), IBM, the Ford Motor Company Fund, Square One Network, and the University. Teams were located at public high schools in Michigan, Georgia, and Puerto Rico. HSE implementation for AY 2010-11 is currently in place at 17 locations and has moved into Illinois. The schools involved with HSE are diverse in locale (rural, suburban, inner city) and in the characteristics of the students they serve (all income ranges, high populations of students from underrepresented groups). Variations among the school types and school districts lead to differences in how HSE implementation evolves at these schools, and the differences are likely required in order to produce successful and sustainable implementations. The flexibility of the HSE program to be implemented in the best manner for the host school is a strength of the program. The basic formula for an HSE implementation is illustrated in Figure 1 by a schematic diagram that emphasizes the team (student) focus of the program and how the basic HSE operating model is grounded in a surrounding multi-base support system formed by partners from industry, higher education, and the local community. HSE does not extract funds from the host schools but, rather, helps those institutions garner financial support from corporate and local stakeholders. There are no prerequisites (academic or otherwise) for participation imposed on students by the HSE program; project interest is the deciding factor. There are in-curricular instances of HSE teams and, in those few cases, prerequisites for participation are a decision of the host school.

High School Enterprise Objectives

High School Enterprise offers secondary students an opportunity to engage in STEM practice in an environment that is at once “real life” with workplace demands/expectations and yet a safe place to try, to fail, and ultimately to learn. It is hoped that HSE equips high school students with the knowledge, skills, and dispositions that will lead more of them to consider STEM careers and that it prepares them for success in the pursuit of those careers. Specific HSE objectives follow.

- All HSE student participants develop and strengthen the eleven essential (i.e., “very important”) applied skills identified for high school graduates by U.S. employers in The Conference Board’s 2006 report *Are They Really Ready to Work?*[1] (percentages indicate the percent of the 352-356 employer respondents who rated the item as “very important” for successful entry-level job performance by high school graduates):

    1. Professionalism/Work Ethic (80.3%)
    2. Teamwork/Collaboration (74.7%)
    3. Oral Communications (70.3%)
    4. Ethics/Social Responsibility (63.4%)
    5. Critical Thinking/Problem Solving (57.5%)
    6. Information Technology Application (53.0%)
    7. Written Communications (52.7%)
    8. Diversity (52.1%)
    9. Lifelong Learning/Self Direction (42.5%)
    10. Creativity/Innovation (36.3%)
    11. Leadership (29.2%)

- HSE student participants are strongly motivated to pursue STEM careers, are more likely to enroll in and complete post-secondary education and training in STEM, and enter the STEM workforce in greater numbers than do non-HSE participants.
- High school teachers are trained and equipped with the skills and resources to implement, coach, and sustain HSE teams.
- HSE teams are sustained through robust and committed partnerships with industry, universities and colleges, foundations, informal science education organizations, community-based organizations, and others as appropriate for the particular HSE instance.
- HSE is a tested, documented, and sustainable model that is adaptable to any high school type and is likely to increase future U.S. capacity in the STEM workforce.
- Enterprise concepts are introduced to middle and elementary school students.

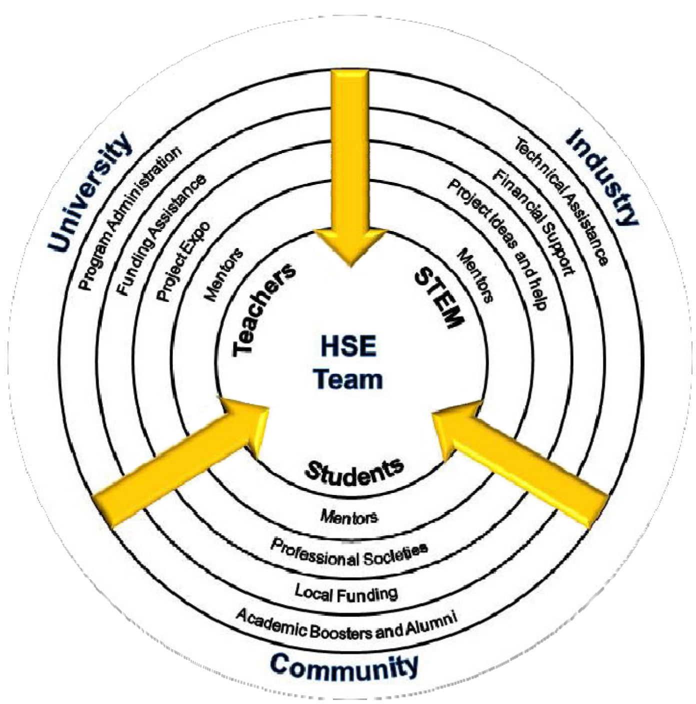

Figure 1 - High School Enterprise operating model.

Supporting Theories

There is agreement among many that K-12 education must undergo a fundamental transformation in order to attract and prepare sufficient students for the domestic STEM workforce (viz., the $4.35 billion *Race to the Top* initiative to reform K-12 education). HSE is designed to engage students through real-world STEM applications based in and supported by their local community, and it offers a viable change vehicle to secondary educators. The guiding core principles of the HSE program follow:

- Content knowledge is not sufficient to prepare K-12 students for the STEM workforce. Students must acquire and develop real-world applied skills.[1] The National Science Board recommends creating faculty and student incentives to reveal linkages between classroom-based skills/experiences and demands on thinking and learning in the workplace.[2]
- Successful after-school programs foster personal and social skills of students and use evidence-based approaches. Durlak & Weissberg[3] analyzed 73 programs and defined four essential attributes: (1) sequenced - coordinated and sequenced to achieve its purpose; (2) active - requires active involvement by the participants; (3) focused – devotes sufficient time to skill enhancement; and (4) explicit – is explicit about program goals.
- HSE is modeled on proven methodologies developed in the undergraduate Enterprise program at Michigan Tech.[4]
- HSE programs must be sustained through robust, committed, and long-term partnerships with industry, academia, and local communities, which follows a recommendation of the National Science Board.[5]

Program Description

General information on teams, coaches, projects, and host locations for HSE implementations in AY2009-10 and AY2010-11 are found in Tables 1 and 2 respectively, and a summary of participant numbers is provided in Table 3. HSE serves a large number of minority and female students, though the ethnic diversity of any given team is usually low. This is not surprising as primary and secondary schools are among the most segregated institutions. HSE, however, is a sufficiently flexible program to adapt to a mode that works best in the host institution and serves the students as the educators of the school see fit. This flexibility is evident in the types of hosts presented in Tables 1 and 2. There are alternative high schools (institutions that often serve as a last resort in public education when traditional institutions do not work for a student), magnet schools, charter schools, traditional public high schools, an Upward Bound program (which serves low-income and first-generation students from many schools), as well as schools that also employ Project Lead the Way (PLTW). So, HSE is flexible enough to facilitate other STEM programs (e.g., PLTW) and to work in highly structured institutions such as magnet and technical high schools. Yet, HSE is also structured enough to offer true implementation assistance to schools that may lack the resources to establish a formal project-based STEM learning initiative on their own. The exact type of implementation for HSE varies among the institutions. Most instances function as afterschool activities, but there are a few cases of in-curricular implementations.

Another important aspect of HSE is evident in comparing the schools listed in Tables 1 and 2 and their team projects. Of the eleven host schools that are continuing from the previous implementation, all of these teams are continuing to work on the same project from last year. This speaks to the long-term nature of HSE projects. Such project longevity is a key factor in truly engaging students in real-world STEM applications and it carries the inherent benefit of providing the time needed for students to fact find and to establish a deep research approach to the project, two aspects of problem solving that have been described as "vital stages in the creative process."[6] Long-term efforts on a continuing project also offer the opportunity for students to fail, often, in their design attempts to solve STEM problems and to try anew, again, learning with each attempt. Frequent failure has been strongly linked to creativity and innovativeness in the workplace and, ultimately, to very successful people.[7] Traditional education is not geared toward failure. High School Enterprise, by virtue of its emphasis on the cyclic engineering design process, is geared toward failure – failure as a structured pathway to success in problem solving.

Support for the implementation of an HSE team comes in many forms and from many sources (see Figure 1). There is a need for financial backing to pay the teacher-coach and to purchase supplies, instruments, equipment, and tools for the project. The funds for this support are initially supplied by the partnering university and, as the team becomes established, the source of these monies moves to industrial and local sponsors. HSE does not extract funds from the host schools or the school districts, and this is another feature of the program that makes it broadly adaptable. The transition to other financial benefactors is facilitated by the program managers at the partnering university.

Technical support is provided to the teams through training of the teacher-coach at week-long summer workshops. All HSE teacher-coaches, new and returning, are presently expected to attend the workshops on the Michigan Tech campus, and they are able to earn continuing education credits for doing so. The week is filled with technical sessions on engineering design, project management, entrepreneurialism, and more. There are social events in the evenings to promote networking and establish a peer support system. The face-to-face interaction goes a long way in affirming the confidence of these secondary teachers to implement project-based learning in STEM areas that may not fall within their areas of expertise. The support is continued through the academic year through on-line meetings that are hosted by the program director. Using Adobe Connect Pro, the teacher-coaches meet biweekly to discuss how their HSE implementation is going and to discuss the best ways to help their students through project road blocks. This on-line venue requires only an internet connection at each host institution. It also offers a chat feature that the program director often uses to gather data in an impromptu fashion on current issues with, or general attitudes about, HSE and working with the student teams. The chat sessions are easily archived and shared with all the teacher coaches on the HSE website (www.highschoolenterprise.org), as are the PowerPoint slides that contain the agenda and the announcements for the on-line meeting. The website itself is also a resource for the teachers and the students, and serves as a portal for them to share project results with the program directors and other teams.

Table 1. Details on High School Enterprise (HSE) teams and host schools for AY2009-10. A summary of participation numbers is provided in Table 3.

	High School and Location	Coach: Content Area	Team Makeup	Project Description	University Partner & Funding Sources
1	**Arthur Hill High School** large urban city Public high school (Gr.9-12) Saginaw, MI 48602	Celeste Conflitti: Biology, Environmental Science	Number of Students: 12 Minority: 11 Women: 6 Grades: 10	DIPLOMATS: Redesign and development of green space on school grounds.	Michigan Tech & NSF - ITEST
2	**B.R.I.D.G.E. Alternative High School** small semi-rural city Alternative high school Hancock, MI 49930	Chuck Palosaari: General Science, Math	Number of Students: 7 Minority: 0 Women: 6 Grades: 10-12	Home weatherization to improve energy efficiency in local homes of the elderly. Learn about thermal imaging technology.	Michigan Tech & Ford Motor Co., Fund
3	**Cass Technical High School** large urban city Magnet school Detroit, Michigan 48201	Ernestine Smith: Business Technology	Number of Students: 12 Minority: 12 Women: 10 Grades: 10-12	IYM (Innovative young Minds): Development of graphics-rich STEM teaching material for elementary grades. First project focuses on solar energy. .	Michigan Tech & NSF - ITEST
4	**Chassell High School** rural town/village Public high school (Gr.9-12) Chassell, MI 49916	Mary Markham: Science, Chemistry, Math	Number of Students: 4 Minority: 0 Women: 0 Grades: 10	INANO: Integrate Vernier sensors and LabVIEW software into LEGO NXT model of an AFM microscope which was constructed AY2009-10.	Michigan Tech & Michigan Tech internal funds
5	**Detroit Institute of Technology - Cody** large urban city Technical high school (new, Grade 9 only in AY2009-10) Detroit, MI 48288-1809	Jeffrey Boykin: Science	Number of Students: 10 Minority: 10 Women: 3 Grades: 9	Vector: Alternative Energy Sources and Innovative Vehicle Design (convert RC gas car into electric).	Michigan Tech & NSF - ITEST, IBM, SqareOne Education Network
6	**Hancock High School** small semi-rural city Public high school (Gr.9-12) Hancock, MI 49930	Brian Rajdl: Physical & Environmental Science Stephen Smith: Language Arts	Number of Students: 16 Minority: 0 Women: 8 Grades: 11-12	PEAK (Partnering the Environment and Academics in the Keweenaw) Study and map the Swedetown Creek area. Stream monitoring and water chemistry. GPS/GIS technologies. Stream Gauging. Land Use and Riparian Protection.	Michigan Tech & NSF-ITEST

Table 1 continued.

	High School and Location	Coach: Content Area	Team Makeup	Project Description	University Partner & Funding Sources
7	**Horizons Alternative High School** small semi-rural city Alternative high school Mohawk, MI 49950	Chris Davidson: Principal, Math/Science	Number of Students: 6 Minority: 0 Women: 4 Grades: 10-12	Home weatherization to improve energy efficiency in local homes of the elderly. Learn about thermal imaging technology, weatherization of homes, and environmental and economic analysis of project(s).	Michigan Tech & Ford Motor Co. Fund
8	**Melvindale High School** large urban city Public high school (Gr.9-12) Melvindale, MI 48122	Randy Thomas: Physics, Chemistry	Number of Students: 37 Minority: 13 Women: 10 Grades: 9-12	Cyber Cards: Design and build a hybrid or fuel cell vehicle	Michigan Tech & NSF - ITEST, Square One Education Network
9	**Manuela Toro Morice School** large urban city Public high school (Gr.10-12) Caguas, PR 00725	Juan Serrano Osorio: Mathematics	Number of Students: 13 Minority: 13 (Latin/Latino) Women: 5 Grades: 10-12	Marine environmental exploration with ROVs and autonomous marine technologies.	Universidad del Turabo & NSF - ITEST
10	**Tech High School** large urban city Charter school Atlanta, GA 30316	Alan Gravitt: Physics, Engineering	Number of Students: 8 Minority: 8 Women: 2 Grades: 10-12	Wearable computer products to help monitor vital signs in athletes and older people during normal exertion.	Georgia Tech & NSF - ITEST
11	**Traverse City Central H.S.** mid-sized city Public high school (Gr.9-12) Traverse City, MI 49686-2875	Keith Forton: Physics	Number of Students: 24 Minority: 0 Women: 4 Grades: 9-12	Design and build underwater ROVs and use ROV technologies to study the marine environment in the Traverse City area.	Michigan Tech & NSF - ITEST
12	**Utica Community Schools** suburban city Utica, MI 48317	Geoffrey Clark: Engineering Technology	Number of Students: 24 Minority: 1 Women: 8 Grades: 11-12	Design and build an underwater ROV for use in the MATE competition. Design and build the EcoKart, an electric go-kart.	Michigan Tech & NSF - ITEST

Table 2. Details on High School Enterprise (HSE) teams and host schools/locations for AY2010-11. A summary of participation numbers is provided in Table 3. PLTW designates a school/host that also implements Project Lead the Way.

	High School and Location	Coach: Content Area	Team Makeup	Project Description	University Partner & Funding Sources
1	**Arthur Hill High School** large urban city Public high school (Gr.9-12) Saginaw, MI 48602	Celeste Conflitti: Biology, Environmental Science	Number of Students: 12 Minority: 12 Women: 6 Grades: 11	DIPLOMATS: Redesign and development of green space on school grounds.	Michigan Tech & NSF - ITEST
2	**Benjamin Mays High School** large urban city Public high school (Gr.9-12) Atlanta, GA 30326	Geraldine Nix: Engineering	Number of Students: 17 Minority: 17 Women: 7 Grades: 9-12	The ELI Project: find creative and artful ways to reuse, recycle, and repurpose potential landfill into what we like to call " Digital Land Art Sculptures."	Georgia Tech & NSF - ITEST
3	**B.R.I.D.G.E. Alternative High School** small city Alternative high school Hancock, MI 49930	Chuck Palosaari: General Science, Math	Number of Students: 10 Minority: 0 Women: 4 Grades: 9-12	Home weatherization to improve energy efficiency in local homes of the elderly. Learn about thermal imaging technology.	Michigan Tech & Ford Motor Co. Fund
4	**Cass Technical High School** large urban city Magnet school Detroit, Michigan 48201	Ernestine Smith: Business Technology	Number of Students: 16 Minority: 15 Women: 11 Grades: 9-12	IYM (Innovative young Minds): Development of graphics-rich STEM teaching material for elementary grades. First project focuses on solar energy.	Michigan Tech & NSF - ITEST
5	**Chassell High School** rural town/village Public high school (Gr.9-12) Chassell, MI 49916	Mary Markham: Science, Chemistry, Math	Number of Students: 6 Minority: 0 Women: 0 Grades: 11	INANO: Integrate Vernier sensors and LabVIEW software into LEGO NXT model of an AFM microscope which was constructed last year.	Michigan Tech & Michigan Tech internal funds

Table 2 continued.

	High School and Location	Coach: Content Area	Team Makeup	Project Description	University Partner & Funding Sources
6	**Dollar Bay High School** rural town/village Public high school (Gr.9-12) Dollar Bay, MI 49922	Matt Zimmer: Math, Science, Technology & Design	Number of Students: 20 Minority: 0 Women: 6 Grades: 9-12	SOAR (Student Organization for Aquatic Robotics): ROV engineering and exploration of local marine environments	Michigan Tech & Michigan Space Grant, Lake Superior Stewardship, Michigan Tech internal funds
7	**Hancock High School** small semi-rural city Public high school (Gr.9-12) Hancock, MI 49930	Brian Rajdl: Physical & Environmental Science Stephen Smith: Language Arts	Number of Students: 14 Minority: 0 Women: 2 Grades: 11-12	PEAK (Partnering the Environment and Academics in the Keweenaw) Study and map the Swedetown Creek area. Stream monitoring and water chemistry. GPS/GIS technologies. Stream Gauging. Land Use and Riparian Protection.	Michigan Tech & NSF - ITEST
8	**Horizons Alternative High School** small semi-rural city Alternative high school Mohawk, MI 49950	Chris Davidson: Principal, Math/Science	Number of Students: 16 Minority: 0 Women: 9 Grades: 10-12	Home weatherization to improve energy efficiency in local homes of the elderly. Learn about thermal imaging technology, weatherization of homes, and environmental and economic analysis of project(s).	Michigan Tech & Ford Motor Co. Fund
9	**Horizons-Upward Bound** large urban city Upward Bound program (low income and first-generation students) of Detroit area Bloomfield Hills, MI 48303	Bill Grimm: Physics, Physical Science	Number of Students: 21 Minority: 20 Women: 12 Grades: 9-10	Wireless Technology and Cell Phone Applications	Michigan Tech & Square One Education Network, Michigan Tech internal funds
10	**Melvindale High School** large urban city Public high school (Gr.9-12) Melvindale, MI 48122	Randy Thomas: Physics, Chemistry	Number of Students: 50 Minority: 23 Women: 11 Grades: 9-12	Cyber Cards: Design and build a hybrid or fuel cell vehicle.	Michigan Tech & ITEST, IBM Corp.

Table 2 continued.

	High School and Location	Coach: Content Area	Team Makeup	Project Description	University Partner & Funding Sources
12	**Tech High School** large urban city Charter school Atlanta, GA 30316	Alan Gravitt: Physics, Engineering	Number of Students: 12 Minority: 12 Women: 3 Grades: 9-12	Wearable computer products to help monitor vital signs in athletes and elderly during normal exertion. We may monitor heart rate, blood pressure, respiration rate, and body temperature. Process and present analysis of body to the wearer.	Georgia Tech & NSF - ITEST
13	**Traverse City Central H.S.** mid-sized city Public high school (Gr.9-12) Traverse City, MI 49686-2875	Keith Forton: Physics	Number of Students: 19 Minority: Women: Grades: 9-12	Design and build underwater ROVs and use ROV technologies to study the marine environment in the Traverse City area.	Michigan Tech & NSF - ITEST
14	**University of Chicago Woodlawn Charter H.S.** large urban city Charter school of University of Chicago Chicago, IL 60637	Assata Moore: Engineering	Number of Students: 23 Minority: 23 Women: 7 Grades: 9-12	Students will study and research seismology by building an earthquake table and researching the effects of fault slippage on the region near Haiti.	Michigan Tech and Illinios Institute of Technology & Self Funded
15	**University Prep Math Science H. S.** large urban city Charter school (with PLTW) of New Urban Learning Detroit, Michigan 48201	Ben Luster: Engineering - PLTW	Number of Students: 13 Minority: 13 Women: 8 Grade: 9	Engineering and STM consulting for other school projects	Michigan Tech & NSF - ITEST, IBM Corp.
16	**Utica Community Schools** suburban city Public high school (Gr.9-12) Utica, MI 48317	Geoffrey Clark: Engineering Technology	Number of Students: 22 Minority: 0 Women: 2 Grades: 11-12	Design and build an underwater ROV for use in the MATE competition.	Michigan Tech & NSF - ITEST
17	**Jackson Schools** Tech Center for Jackson schools with PLTW Tech Center, Jackson, MI	PLTW teacher	Grades: 9-12	Project Lead the Way Capstone project	Michigan Tech & Self Funded

Table 3. A summary of HSE participants for the ITEST implementations of AY2009-10 and AY2010-11. Details on these implementations are found in Tables 1 and 2.

HSE Implementation	AY2009-10	AY2010-11
Number of host sites	12	17*
Students:		
Total number of students	173	286
Average number of students per team	14	18
Number of female students	66 (38%)	99 (35%)
Number of African American students	39 (23%)	107 (37%)
Number of Hispanic students	23 (13%)	34 (12%)
Number of "other" minorities	6 (3%)	13 (5%)
Teachers:		
Total	13	17
Number of STEM teachers	12	16
Number of female teachers	3	5
Number of ethnic minority teachers	2 (1 female)	4 (3 female)

* Numbers for Jackson Schools (#17 in Table 2) are not available at this time and, hence, not included in the counts and percentages below this cell.

Face-to-face interaction for the students on the teams is achieved each spring when the participant students visit the campus of the partnering university to present their project work at an undergraduate EXPO. The secondary students design and create posters that are presented in the same showing as those for the undergraduate projects. The HSE teams are also required to give an oral presentation on their work to an audience that comprises the other HSE teams and teacher-coaches, university faculty, and undergraduate engineering students who serve as presentation judges. A representative from the external evaluation team for the NSF grant-work also scores the presentations and posters of the secondary students. Bringing the HSE students to campus allows them to network, but it also serves the important function of making the university accessible to them. Many HSE student participants do not have ready access to a university or see a clear pathway to higher education for themselves. HSE has the potential to motivate students to take that path and to actually provide the hope that is critical in establishing that path to post secondary education.

Mid-Program Results and Discussion

The assessments used in evaluation are linked to annual program activities. The NSF-ITEST work has an external evaluation team from the Science and Mathematics Program Improvement (SAMPI) group at Western Michigan University, and SAMPI representatives administer the majority of assessments for the HSE exploratory ITEST project.

High School Enterprise establishes teams of secondary students that work on long-term STEM projects under the guidance of a teacher-coach who is specially trained to implement this project-based learning experience. Most instances of the program operate in an afterschool mode, but a few run as in-curricular classes. Depending on the type of implementation at a host site, secondary students can participate on HSE teams for one or more years. We have established cadre names to identify the start date of participant students and of participant teachers. Cadre I defines a group of students or teachers who began their HSE experience in fall 2008. Cadre II students and teachers began in fall 2009, and Cadre III in fall 2010. It is important to note that the "cadre" label applies only to people and that it defines the level of treatment for people at any given time. For example, a Cadre I student who is still participating in HSE has, in fall 2010, begun his/her third year of HSE, and a Cadre II student has begun his/her second year. It is not meaningful to label a school with a "cadre" designation because in all HSE instances, students will join and leave the program each year. For many afterschool instances, students may join HSE as 9th, 10th, 11th, or 12th grade students and continue to participate until graduation – or not. In these cases, a particular HSE team may now have students from Cadres I, II, and III. For most in-curricular instances of HSE, students participate for only one year, and each fall the cadre number associated with all the HSE students at these sites advances because each fall a new group of students begins the HSE class. In Hancock Central High School, for example, all current HSE students are Cadre III students but the two coaches are Cadre I teachers, and the host site (i.e., the school) had only Cadre I students in AY2008-09, only Cadre II students in AY2009-10, and currently has only Cadre III students this year.

SAMPI assessment methods include the following items, which are each associated with an annual program activity:

- A comprehensive pre-test survey of all new students entering HSE and an annual post-test survey of *all* students in the program. The survey covers a wide range of topics such as self-assessment of various workforce skills, technology skills and use, attitudes toward STEM, and college and career intentions. This survey consists of scaled-response items. We note here that, in the AY2008-09 implementation of HSE that was funded by NSF through the IEECI program (EEC-0835670), the pre-treatment survey was administered to test the instrument, but a post-treatment administration did not occur until spring 2010, at the end of the second year of treatment for Cadre I students and at the end of the first year of treatment for Cadre II students.
- A pre- and post- survey of teacher-coaches (upon starting to coach a team and annually thereafter) that covers a range of skills needed by teachers to coach HSE teams (such as IT knowledge and usage and preparedness to use selected instructional strategies).
- A teacher-coach summer workshop questionnaire completed annually by teacher-coaches.
- An Expo survey (open-ended questions) of students who participate in the undergraduate spring EXPO. We note here that not all HSE students travel to the spring undergraduate EXPO, but most do.
- Direct evaluator assessment of student team EXPO presentations and posters.
- Evaluator site visits and/or teacher-coach interviews.

Cadres I and II students and teacher-coaches have participated in all assessment activities, as described above, up to this point. Cadre III students and teacher-coaches have participated only in the pre-treatment assessment activities of fall 2010, and because results from these pre-treatment assessments have, as yet, no bearing on the evaluation of the treatment program (HSE), they are not included here.

Spring 2010 HSE Students Evaluation Results from SAMPI

Student Workforce Skills:

- Cadre I students were asked to rate their applied work skills on a 5-point scale. Of the 14 items, the pre-to-post mean change was positive for ten items and no change for four items. Four of the positive items were statistically significant pre-to-post, including "I can verbally communicate my ideas clearly and effectively," "I work easily with people who are different from me," "I can help others develop their skills," and "I can come up with original ideas to solve problems."
- Cadre II students were asked to rate their applied work skills on a 5-point scale. Of the 14 items, the pre-to-post mean change was positive for ten items, negative for two items, and no change for two items. No pre-to-post mean changes were statistically significant. Possibly, this is because Cadre II students had been in the program for only one year at the time of the post-treatment survey.

Student Technology Skills:

- Cadre I students were asked to rate their technology skills on a 0-3-point scale. Of the 20 items, the pre-to-post mean change was positive for 15 items, negative for four items, and no change for one item. Seven of the positive items were statistically significant pre-to-post, including "social networking," "database software," "blogs," "podcasting," "modeling software," "computer game development software," and "robotics programming software."
- Cadre II students were asked to rate their technology skills on a 0-3-point scale. Of the 20 items, the pre-to-post mean change was positive for 11 items, negative for one item, and no change for eight items. Six of the positive items were statistically significant pre-to-post, including "spreadsheet software," "graphing calculators," "database software," "modeling software," "computer game development software," and "robotics programming software."

Student Technology Use:

- Cadre I students were asked to rate their technology use on a 0-3-point scale. Of the 17 items, the pre-to-post mean change was positive (+.05 change or more) for ten items, negative (-.05 or more) for four items, and no change (less than + or - .05) for three items. Three of the positive items were statistically significant pre-to-post, including "Develop scientific models showing how complex systems actually work," "Program robots with computer software," and "Analyze numerical data and create displays of the results."
- Cadre II students were asked to rate their technology use on a 0-3-point scale. Of the 20 items, the pre-to-post mean change was positive (+.05 change or more) for 11 items, negative (-.05 or more) for one item, and no change (less than + or - .05) for eight items. Two of the positive items were statistically significant pre-to-post: "Create pictures or design posters using technology" and "Program robots w/computer software."

Student Perceptions of HSE Experiences: At the end of each academic year, most HSE students attend the spring undergraduate EXPO and complete a questionnaire with open-ended questions covering a wide range of topics: best aspects of HSE, most challenging aspects of HSE, most important things learned, new technologies learned, communication skills learned, and teamwork skills learned. The responses are coded and ranked, and the full results are found in SAMPI's report. Here we summarize the results for just two items – the last items of the questionnaire:

- "**Would you encourage other students to participate in a similar project in the future?"** In the spring of 2009, 44 of the 45 Cadre I students responding said they would encourage other students to participate in a similar project. In the spring of 2010, all 73 students responding (20 Cadre I students and 53 Cadre II students) stated that they would encourage other students to participate.
- **Career Intentions:** *At the end of their first year in HSE*, 70% (32 students) of Cadre I (n = 46) and 61% (34 students) of Cadre II students (n=56) who attended spring EXPO and completed the open-ended questionnaire indicated that they are considering STEM careers. Longitudinal data will continue to be collected for students so we can learn if attitudes about career intentions in STEM are changing with HSE experience.

SAMPI Evaluator Assessment of Team Expo Presentations and Posters

Each spring, HSE teams present their projects on campus at the Michigan Tech Undergraduate EXPO. The external evaluator conducts direct assessment of the student team project posters and presentations. Oral presentations are judged on introduction, content, text, graphics, oral presentation skills, scientific rigor of the project, and writing mechanics and quality. Poster presentations are judged on purpose, content, text, graphics, scientific rigor, and writing mechanics and quality. Table 4 below shows the mean results for teams combined according to their start date. What is particularly compelling is the improvement in skills of all AY2008-09 start teams from their first year of participation to their second year. It should be understood that these teams very likely had both Cadre I and Cadre II students as members, while the AY2009-10 start teams had only Cadre II students.

HSE Teacher-Coaches Evaluation Results

All teacher-coaches participate in the five-day Summer HSE Workshop. Workshop sessions are intended to train teacher-coaches to implement a long-term STEM project-based learning experience for their students. The workshop consists of several interactive and practical presentations. Workshop topics include project management, STEM projects, engineering design, and fundraising/marketing for sustainability. Table 5 presents combined survey responses from Cadre I and Cadre II teacher-coaches who attended the 2010 Workshop. Their responses indicate strong agreement that the summer workshop provides valuable content and skills development for the teacher-coaches.

Table 4. Direct SAMPI assessment results from student team EXPO presentations and posters.

Expo Activity	HSE Teams begun in AY2008-09 (First Cohort)		HSE Teams begun in AY2009-10 (Second Cohort)
	Spring 2009 EXPO Mean Results	Spring 2010 EXPO Mean Results	Spring 2010 EXPO Mean Results
Oral Presentation (35 total points)	22.75	27.25	22.00
Poster Presentation (30 total points)	22.75	25.75	22.75

Table 5. Combined responses from Cadre I and Cadre II teacher-coaches to the Michigan Tech on-line overall workshop assessment for the 2010 Summer Workshop.

2010 Summer Workshop SurveyMonkey Questions (Developed by Oppliger in 2009)		**Response % of total (n=12)**
The number of session topics was:	Too many	25
	Just enough	75
	Too few	0
Compared to where you were before, what is your confidence level in your ability to coach an HSE team after attending this workshop?	Much greater	58.3
	Greater	41.7
	About the same	0.00
	Less	0.00
Compared to where you were before, what is your level of understanding of the goals of the HSE program?	Much greater	58.3
	Greater	33.3
	About the same	8.3
	Less	0.00
Compared to where you were before, what is your level of motivation to coach the HSE team at your school?	Much greater	45.5
	Greater	45.5
	About the same	9.1
	Less	0.00

Notable Other Findings

Finally, although this was not part of the formal evaluation, we conducted a survey of the 33 Math Science Centers in Michigan (these centers are liaisons between the state and local school districts) to determine interest in HSE programs state-wide. When asked if they would lead the effort within their regions to build an HSE program if they were provided with seed funding (diminishing over a 3-year period), 19 (86.4%) of the 22 responding Centers answered "yes."

Conclusions

High School Enterprise is a flexible, adaptable program that engages secondary students in STEM learning through long-term projects. It offers students a vehicle to practice real-world STEM application and seems to motivate students to consider STEM majors in post-secondary education and to consider STEM careers.

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