Douglas E. Oppliger, Michigan Technological University

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.

Prof. Valorie Troesch, Michigan Technological University

Jean Kampe, Michigan Technological University

DR. JEAN KAMPE is currently department chair of Engineering Fundamentals at Michigan Technological University, where she also holds an associate professorship in the Department of Materials Science and Engineering. She received her Ph.D. in metallurgical engineering from Michigan Tech, an M.Ch.E. in chemical engineering from the University of Delaware, and a B.S. degree in chemical engineering from Michigan Tech. She was employed as a research engineer for five years at the Naval Research Laboratory in Washington, DC, and she held an associate professorship in the Department of Engineering Education at Virginia Polytechnic Institute and State University, working there for ten years in first-year engineering education.
A solution to a physics problem
This story begins with a high school physics teacher looking for a “real world” ways to demonstrate physics principals. This particular teacher lives and works in Traverse City, a small city in northwest Michigan situated on Grand Traverse Bay. The local community values the natural environment surrounding the town, especially the bay. The teacher is a lifelong resident of the community and has spent a great deal of time on the local waters at work and at play. When he first heard of using simple materials like PVC pipe and bilge pump motors to build underwater ROVs (remotely operated vehicles) he thought it might be a good way to combine his avocation with his vocation and generate enthusiasm for physics among his students. When he started down this path he had no notion that his decision would lead to something that, as he likes to say, “Has taken on a life of its own!” After several years, ROV is now a commonly used acronym in the school and indeed the whole community. His initial efforts were largely built around participation in the Great Lakes MATE (Marine Advanced Technology Education) competition¹. After achieving success in these competitions and even sending students on to compete at the national level, he and his students started to turn their attention to how ROVs could be used to explore the waterways near the school. In order build up the aquatic studies aspect of the program, partnerships were developed with Michigan Technological University and other resource providers. These now mature partnerships have helped establish educational ROVs programs not just in Traverse City, but all across the Great Lakes.

This paper discusses the development and results of these partnerships as examples for others who may want to start similar programs. It begins with a presentation of the parent program at Michigan Technological University which supports this particular team along with many other teams working on projects other than ROVs. Evidence will be presented showing the success of the parent program in recruiting and motivating students to study STEM (science, technology, engineering, and mathematics). The paper next details the operation of the ROV engineering team at Traverse City Central H.S. and the partnerships that help it thrive. The paper gives examples showing what and how students are learning through their participation. The paper concludes with recommendations on how other universities can develop similar partnerships to create interest in ROVs, ocean & marine studies, and STEM learning in general.

The ROV engineering team at Traverse City Central High School (TCROV) is one of many teams that participate in the High School Enterprise Program. This parent program exists to support teams of students working on long-term STEM projects. The High School Enterprise program provides a framework to help schools and teachers start and sustain these teams and make them part of the fabric of the school’s culture, much like sports teams. In order to explain the partnership between TCROV and Michigan Tech, the following sections of this paper describe the parent program (High School Enterprise), and the research into what and how participating students are learning.
High School Enterprise – Student teams, STEM projects

High School Enterprise (HSE) was an outcome of a December 2004 report generated by Michigan Lieutenant Governor John Cherry’s roundtable commission that addressed the issue of how to create a 21st century Michigan workforce. In response to this report, representatives from Michigan Tech began investigating ways to increase linkages with K-12 education. They sought to motivate and prepare more students for higher education and STEM careers. Among the multiple initiatives undertaken was High School Enterprise. The university agreed to fund a small, one-year test program in three Michigan high schools for the 2007-2008 school year. Based on positive preliminary outcomes, a pilot HSE program was subsequently supported by NSF through a one-year IEECI (EEC 0835670) award and then a three-year ITEST (DRL 0833542) award. The ITEST pilot program will undergo its final year in 2011-12.

For more information about the High School Enterprise program: www.highschoolenterprise.org

HSE is premised on the principle that active, discovery-based, and team-based learning environments are effective at enabling students to apply content knowledge to problem-solving and to help prepare them to successfully pursue post-secondary STEM education. It borrows from project-based, problem-based, and inquiry-based learning models. Barrows defined six core characteristics of problem-based learning: learning must be student-centered; it must take place in small groups under the guidance of a tutor; the tutor must function as facilitator or guide; authentic problems are encountered in the learning sequence before other preparation or study; problems are used as tools to acquire the knowledge and skills to solve the problem; and new information is acquired through self-directed learning. The Buck Institute for Education, which focuses on project-based learning, identifies a similar set of essential elements: “organized around an open-ended Driving Question or Challenge; creates a need to know essential content and skills; requires inquiry to learn and/or create something new; requires critical thinking, problem solving, collaboration, and various forms of communication; allows some degree of student voice and choice; incorporates feedback and revision; and results in a publicly presented product or performance.” Key HSE program attributes include the following:

- HSE creates a robust communication network between higher education and HSE teams through mentoring and on-campus opportunities to present their work. Students are thus exposed to post-secondary STEM education throughout their HSE experience, which creates the expectation that they will continue STEM study after high school. HSE motivates students to prepare for higher education – to be college ready upon graduation from high school.
- HSE creates a culture of active discovery-based learning that can be centered around an in-school or extracurricular experience according to the needs of the school.
- HSE can complement other programs (e.g., Project Lead the Way and FIRST Robotics) by providing a flexible implementation of project-based STEM learning that facilities the goals of the other programs.
- HSE is designed as a self-sustaining program to bring resources into the school from industry, the local community, and academia. These resources include project funding, support for a coaching stipend (akin to the pay athletic coaches receive) and support for other HSE program costs such as travel.
- HSE fosters enthusiasm and excitement about STEM learning by putting tools and technology into the hands of the problem solvers—the students! It gives them a chance to discover, a chance to fail, and ultimately a chance to succeed with a project for which they have a passion. This will
lead to students following through with their college STEM educations and their eventual entry into the STEM workforce.

- **HSE is a proven success in many different socioeconomic environments, including rural and urban low-income, at-risk populations. HSE has also recruited and retained significant numbers of students from groups underrepresented in STEM such as women and minorities.**

Additionally, high school teacher-coaches acquire important skills through their HSE training and experiences in the program. They are immersed in an integrated structure in which they learn how to implement project-based learning, how to manage a team working on a project outside their area of expertise, and how to generate and sustain enthusiasm for STEM learning among the team participants. The HSE program model offers ongoing support through program manager organization and expertise, university and industry partner expertise, recognized professional development (continuing education credit for workshop participation), and peer support. Figure 1 depicts the program’s operational model for HSE teams.

Over the past several years, many studies have suggested that content knowledge alone is no longer adequate to prepare students for the STEM workforce and that they must also develop real-world, applied skills. K-12 instruction that focuses more on process than pure content is a recommendation that has strong support. Karen Bruett, director of K-12 business development for Dell, echoes the advice of many technology companies who seek a larger and well prepared STEM workforce: “Don’t focus on the technology; focus on instruction and how the tools can be applied to gather and share information with a team trying to solve the problem.” In Realizing America’s Potential, the National Science Board (NSB) recommends creating faculty and student incentives to reveal linkages between classroom-based skills and experiences and the demands on thinking and learning in the workplace. Meta-analyses that have compared problem-based learning (PBL) to conventional classrooms have concluded that PBL is “superior when it comes to long-term retention, skill development and satisfaction of students and teachers.” Finally, a recent report to the President of the United States makes this statement: “STEM education is most successful when students develop personal connections with the ideas and excitement of STEM fields. This can occur not only in the classroom but also through individualized and group experiences outside the classroom …” Based on these analyses and, now, on results from our own pilot High School Enterprise program, we believe that project-based learning can help address many of the concerns being voiced by educators and other stakeholders who are concerned with education outcomes.
HSE is premised on the belief that project-based learning is not simply another route to the same result: that, in fact, HSE participation (1) is a strong motivator for students to graduate from high school and pursue post-secondary STEM training, (2) develops the academic and workforce skills needed to succeed in post-secondary STEM training, and (3) is effective in recruiting students from groups that are currently underrepresented in STEM. Achieving these results, however, has a cost. Our belief is that systematic, programmatic, expanded, and sustained discovery-based STEM learning, such as that offered by HSE, requires a framework that encompasses both substantive and organizational support that, in turn, requires commitments which vary from conceptual support from the schools and school districts (i.e., figurative “buy-in” to the program), to time, to funding, to technical expertise, and to cultural tenacity from industries, communities, teachers, and parents.

Results from assessment of the HSE program
The HSE program began with three high schools (small rural school, large Detroit inner city school, and suburban Detroit school) and three HSE teams. The program now has 16 teams, which is the capacity that can be managed and supported with current hub resources. These HSE host schools represent a broad range of demographics, as shown in Table 1 below. Schools are located in Michigan (13), Georgia (2), Illinois (1), and Puerto Rico (1). About one-third of the schools are in rural areas. More than half are urban. Over 80% are low income, 56% are high minority, and 56% have high populations of at-risk students.

<table>
<thead>
<tr>
<th>High School and Location</th>
<th>Rural</th>
<th>Urban</th>
<th>Low Income</th>
<th>High Minority</th>
<th>At Risk</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Arthur Hill H.S., Saginaw, MI</td>
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<td>Tech High, Atlanta, GA</td>
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<td>Manuel Toro H.S., Puerto Rico</td>
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<td>U of Chicago Woodlawn Charter H.S., Chicago, IL</td>
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<td>Jackson Schools, Jackson, MI</td>
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* The HSE implementation at Traverse City High School has expanded to include a middle school Enterprise team that is mentored by the secondary HSE students.

HSE has also attracted high participation among women and minority students, groups that are underrepresented in STEM. As shown in Table 2, 35% of all HSE student participants are female and 54% are from minority groups, principally African-American and Hispanic.
### Table 2 - HSE 2010-2011 Team Statistics

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<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Total participating students</td>
<td>286</td>
</tr>
<tr>
<td>Total teams</td>
<td>16</td>
</tr>
<tr>
<td>Average number of students per team</td>
<td>18</td>
</tr>
</tbody>
</table>

#### Student Demographics

<table>
<thead>
<tr>
<th>Gender</th>
<th>Number of Students</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>99</td>
<td>35%</td>
</tr>
<tr>
<td>African Americans</td>
<td>107</td>
<td>37%</td>
</tr>
<tr>
<td>Hispanics</td>
<td>34 (15 from Puerto Rico)</td>
<td>12%</td>
</tr>
<tr>
<td>Other minorities</td>
<td>13</td>
<td>5%</td>
</tr>
</tbody>
</table>

An additional important demographic result is that of diversity among the teacher-coaches. Although women are underrepresented in STEM, five of the HSE teacher-coaches are women and three of them are from minority groups. Having diverse role models is an important factor in motivating diverse students to pursue STEM education and careers. Maintaining the diversity of teacher-coaches is an ongoing objective of the project.

The Science and Mathematics Program Improvement (SAMPI) Center, Mallinson Institute for Science Education, at Western Michigan University serves as the external evaluation team for the HSE ITEST project.

Assessment methods included the following:

- A comprehensive pre-test survey of all new students beginning HSE participation 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.
- Surveys 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 (e.g., IT knowledge and usage and preparedness to use selected instructional strategies).
- Teacher-coach Workshop questionnaire completed annually by teacher-coaches.
- Annual debriefing interviews with teacher-coaches.
- Expo survey (open-ended questions) of students who participate in the university research Expo.
- Direct assessment of student expo presentations and posters.
- Site visits and teacher-coach interviews conducted by the project evaluators.
- Data collection on student demographics.

ITEST project assessment data will be collected through the 2011-2012 school year, but preliminary results are promising and are summarized here:

#### Evaluation Results: HSE Students

**Student Workforce Skills:** students report gains in workforce skills such as collaboration, professional communication, and teaming skills. (Figure 2)
Student Technology Use and Skills: students are able to identify multiple technologies that they have learned, and/or used extensively, as a result of their project work. Examples given include: “modeling software,” “computer game development software,” “robotics programming software” and “Analyze numerical data and create displays of results.”

Career Intentions: At the end of their first year in HSE, 65% of students indicated that they are considering STEM careers. Longitudinal data will be collected to follow student attitudes and actions concerning post secondary STEM intentions.

Perceived Value of HSE: In spring 2009, 44 of 45 responding students said they would encourage other students to participate in HSE or a similar project. In spring 2010, all 73 responding students stated that they would encourage other students to participate in HSE.

The above information pertains to the HSE program as a whole. Now let us look specifically at the TCROV team and evidence of student learning resulting from their ROV centered projects.

The TCROV Team, what it is & what is learned
As stated earlier, the plan to bring ROVs into this school was intended to bring relevance to physics students. The seed for using ROVs actually came from a few students who wanted to participate in a ROV competition and approached the physics teacher for help. The teacher immediately saw the value of using ROVs to demonstrate physics principals and an informal ROV program was born. The teacher’s expertise and enthusiasm in the subject of light-duty educational ROVs grew and he was asked to facilitate a workshop so other teachers could get the basics and perhaps start programs of their own. The workshops were sponsored by the Square One Education Network, whose mission is to get “gear” into the hands of teachers and students.
to excite and motivate studies in STEM. The first workshop was so successful that a formal curriculum has been developed complete with a textbook. Over the past four years, five more workshops have been conducted with financial support Square One, Michigan Tech, the Michigan Space Grant Consortium, and other sources. Over 100 educators from around the Great Lakes have participated in these workshops affecting many hundreds of students. Notably, nearly 40% of all workshop participants to date have been women. (Figure 3)

Figure 3: STEM Teachers build, and then test their self-made ROVs at a workshop in Detroit

In addition to sponsoring workshops, Square One also supplied the TCROV team with funds to support their project work. The teacher, however, was still doing the “coaching” as an afterschool volunteer, which wasn’t a sustainable situation. There was a need for more support to help the program become part of the cultural fabric of the school, much like a sports team.

This is where the University connection begins and becomes important for several reasons. The HSE program provided the framework to help create a team built around doing long-term STEM projects, in this case with ROVs as the central theme. HSE provided a stipend for the teacher (now called an HSE teacher-coach), as well as project funds and technical support from college students. The teacher-coach benefitted from attending the one-week summer HSE coaches’ workshops and the regularly scheduled on-line coaches’ meetings described earlier. Finally, the HSE program director supports this coach (and all coaches) on an as-needed basis. This help comes as a result of regular communication using phone, email, and semi-annual site visits to the team by the program director. With the help of this framework of support, the TCROV team was started in fall 2008. This year (2010-11) will be its third in the HSE program. The team currently has a roster of 19 students; 13 boys and six girls. The team meets after school, typically one night a week, but more often when competition or presentation deadlines are looming.

The HSE support framework allowed the TCROV team to branch out beyond the MATE competition and consider how ROVs could be used to explore and learn about their local waterways. Several side projects have been undertaken since the HSE team started. Some of these were initiated by the MATE competition challenges while others were conceived and developed solely by the team. This latter type is where the real power of project based learning comes to bear. Students develop their own “Driving Question” then plan a strategy to answer that question. They work throughout the process to communicate the problem/need and the solutions...
as they are developed. In the spring of each year the work is presented publicly on a university campus and other venues. This process cycle brings with it unmatched learning opportunities.

Figure 4: The MATE Competition sparked great interest among these middle school students

**Educational Goals and Objectives of the TCROV team**

The TCROV team is constantly working to develop more and more advanced ROVs. Their first efforts included simple vehicles with video cameras and perhaps end effectors of some type. These machines were used in relatively shallow water (10 – 20 feet) mostly to capture video and explore underwater. The team is now working on ROVs to explore to depths of more than 200 feet, and in addition to video, transfer digital signals from onboard sensors to the surface where they will be displayed with the camera’s video output. In trying to achieve this “deep water” goal, the team regularly encounters problems, which lead to even more project driven solutions. We will now present the basic “classroom learning objectives” that are met by the ROV program, then move to the more powerful (deeper) learning provided by the project work. The design and building of the ROV is, in itself, a project filled with many STEM concepts that students will learn and practice. Some of these concepts include the following:

- Forces and Buoyancy (inherent in moving the ROV in its underwater environment)
- Material properties (selecting materials for a specific purpose)
- Electricity and Electrical Energy (power to motors and electronics)
- Wiring and circuits (controls and power)
- Optics (camera and video)
- Electronics (sensing probes, camera, controls)
- Video imaging (harnessing video signal, capturing and playing recordings)
- Information analysis (deciphering images and probe readings during and after exploration missions)
- Navigation in 3-D space (using geometry and trigonometry concepts to locate positions underwater)
- Spatial visualization (an important learned skill for STEM fields of study)[ref]
- Engineering Design (basing vehicle design on specific criteria and constraints)
All of these are closely tied to Michigan’s science standards and High School Content Expectations. Each of these is also addressed in the book.

Beyond these concepts, as students look at the “big picture” of an ROV solution they are forced to grapple with the real-world and all the problems it presents. For example, as students started working the problem of taking a very light observation class ROV to deep water, they immediately saw that the tether was going to be a huge issue. Because of the long tether, drag forces will completely overcome the available power. So now the students need to do several things such as:

1. Research and test to determine the thrust potential of their current motors.
2. Look into what other motor (and hence power supply) options are available.
3. Research tether drag forces and look into ways to reduce or eliminate them.

These tasks invariably lead to more questions, potential solutions, and more learning at a very deep level.

Another benefit of project learning, and exemplified by the TCROV team, is that students learn a great deal by experiencing a certain degree of failure. In an ordinary school setting, failure is generally avoided at great cost. Textbooks and teaching methods are often designed to protect the student from failure because there isn’t enough time to deal with the inefficiency of this allowance. In project work however, it’s “part of the deal” and students learn (at least) that failure isn’t always catastrophic or the end of the problem. Although the HSE program has not done research into what participating students learn from failure, there are many observations from coaches and students that provide insight. Here is an example for the TCROV coach:

HSE is designed as a non-competitive program that allows students to fail without an external penalty. As a coach I try to prevent failure but it happens. Since there is no [grade] penalty, students can, and have, taken on some pretty stiff challenges taking a substantial risk that project goals may not be reached. As a coach you have to filter those projects that present a substantial challenge versus those that are impossible.

I have found that failure exists at two levels:

1) Incremental failure: those small failures during the design and building process that force students to go back and analyze their initial thoughts, ideas or a strategy. This type of failure is a great learning tool. It usually points to a new strategy. This emphasizes the need for evaluation and testing during the design process. My usual reply is "you discovered a method that does not work!"

2) Catastrophic failure: The whole project collapses in front of you in a short time. This is usually due to some minor, seemingly insignificant, overlooked aspect of the project (attention to detail). Although a coach does not like to see this it too can become a great learning tool, if and only if, the group goes back and looks at the reasons for failure. This almost always can get traced back to skipping the "test and evaluation" portion of the design process.

As a coach you walk a fine line between being too overbearing, the project becoming your project not the students, versus trying to guide the students in the process and
hopefully away from a catastrophic failure. You also have to closely monitor the frustration levels and intervene when necessary.

When students participate in team-based, long-term STEM projects, the learning will not be as we typically plan it for a classroom setting; i.e. it will not be as “today we will learn X, tomorrow Y, and so on.” One key to measuring this learning is the documentation of artifacts produced as students.

Students working on projects WILL LEARN, it’s just hard to pinpoint ahead of time exactly what will be learned. With this in mind, let’s turn to some of the current projects of the TCROV team.

The HSE program requires that each team submit a set of goals at the start of the year. It is expected that these will be modified as the year progresses, and this is almost always the case. Here are the goals submitted by the team in NOV 2010:

TCROV – 2010-11 Goals

The following is a brief synopsis and summary of potential goals for the HSE underwater ROV engineering project, Traverse City Central Senior High, Traverse City Michigan.

The emphasis for 2010-2011 will involve three high school teams concentrating on five primary areas:

1) Increase the use of technology into the ROV system and building process. Possible areas may include:

a) Integrating microcontrollers (Basic Stamp®) into the ROV control system
b) Interlacing text and sensor information into the video output display
c) Developing microcontroller based sensors that can relay information back to the surface

2) Design, engineer, build and evaluate a ROV that uses a “wireless control system”. The ROV may include the following:

a) Internal power supply
b) Wireless motion control
c) Vectoring motor configuration to allow sideways translation
d) Wireless transition of video and audio

3) Design, engineer, build and evaluate a ROV that is capable of reaching 200’ of depth. The ROV may include the following:

a) Internal power supply
b) RC control
c) External lighting
d) An optical system suitable for a no light environment

4) Compete in the regional Great Lakes MATE competition for those who wish.

5) Make a concentrated effort to support and mentor a ROV engineering teams at the middle school level. Evidence suggests that students, when exposed to the novelty of ROV building at an early grade level, will stay together and continue ROV engineering as they progress through future grade levels. One anticipated problem would be finding competent parent mentors to stay with each team.

Respectfully submitted,
Traverse City Central ROV Enterprise Team, NOV 2010

Guided by these goals, the 19 person team divided into sub-teams of three to five students. Each sub-team focusing on one (and sometimes more than one) goal. The following section looks at a few of these side-projects to give the reader more detail about how the team functions. The first three examples are projects in the realm of engineering (creating devices and systems to meet a need), followed by some examples in basic science (learning through careful observation and experimentation).

After using ROVs to view and record video images, it became clear to the team that it would be useful to be able to translate the ROV both fore & aft and sideways. This would allow video to be taken of a long feature, such as a rock wall, or dock support system by moving the camera parallel to the long dimension of the feature. An ROV that can translate in this fashion would be useful in other ways too, such as maneuvering an end effector into position. Prior to this year, none of the team’s ROVs had this capability, but as shown in Figure 5, this is no longer the case. There is still much work to be done to complete the control system, which will eventually be based on a Basic Stamp® microcontroller, but the team is happy with the initial testing of this system.

Figure 5: Prototype board for “vectoring” motor configuration and test model ROV
In order to test components, such as home-made cameras, for use at depths up to 300 feet, the team built a small test chamber. This device is still in development, but a test model is shown in Figure 6. To be safe, the device needs to withstand pressures of about 300 psi (about double the 300 ft. pressure). The team's teacher-coach is very conscious of using this device in a safe manner and controls the project very tightly. This is an example of how a coach needs to gauge the proper amount of involvement in a project.

Figure 6: Team-built pressure chamber to test water-proof camera designs

As presented in the TCROV team’s goal statement above, they have an ambitious objective to operate a useful ROV in some of the deeper waters of Grand Traverse Bay. Their goal of operating at depths of 200 feet brings with it a multitude of problems to solve, and side projects to complete. One of these problems/projects is sending sensor information to the surface through a manageable tether and displaying, as done with commercial ROVs, as text information on the camera’s video output screen. This project has been a fantastic challenge for the students (and mentors!) involving electronics, microcontrollers, computer programming, video signals, and a lot more. Figure 7 shows the results of one test where a temperature sensor output is deciphered by a Basic Stamp microcontroller and sent through a 300 foot tether to be displayed on the video screen.

Figure 7: Interlacing Sensor Signals with Video. The team’s goal is to display temperature, depth, and heading information transmitted via wire or fiber optic strand. The team is using Parallax Basic Stamp® technology for its microcontroller.
This is an example of a side project where the teacher-coach (along with team members) is walking the line between providing a “black box” solution (one where a device is purchased to do what is needed in a plug-and-play fashion) and one where the students build a solution with simple electronic components. In this case, the students used an on-screen display videotext overlay character generator along with Parallax Basic Stamp® technology (not a great deal of computing horse power) to accomplish their goal. They are now working on displaying both depth and heading, which when accomplished will give them an ROV with near-commercial observation capability; an impressive feat for students in 9th -12th grades.

Grand Traverse Bay (the main body of water close to the team’s host school), like all of Lake Michigan, is susceptible to zebra mussel colonization. Zebra mussels are an invasive species whose presence has many environmental implications, many of which are probably still to be discovered. The TCROV team has documenting the colonization at a local marina (Figure 8) which shows colonies on dock chains that were installed two years before these photos were taken.

Note the extreme clarity of the water in Figure 8, which is attributed in part to the zebra mussels filtering ability. A good thing at times, but long term effects may not be positive. This fact and many other things about the mussel infestations have captured the attention of the TCROV students and have led to the team developing experiments to help learn more about the mussels. An example is shown in Figure 9, where a clear plastic plate was divided into four sectors, with each sector given a different surface treatment.
The idea for this experiment came from observations that the mussels are selective as to which surfaces they adhere. Students observed large colonies in one location (such as a dock chain), but no mussels in nearby locations (certain rocks or structural components). The idea was to place this plate in an area where mussels might start to colonize and see where (if?) any colonization takes place. This experiment (regardless of outcome) is a powerful demonstration of the learning opportunities offered by the TCROV and similar programs. Oh yes, the results of this experiment … still to be determined. Stay tuned!

Grand Traverse Bay, like most of the Great Lakes shoreline, is covered in ice for the greater part of the school year. This can make underwater exploration difficult in times other than early fall and late spring. This is a problem for many projects because the heart of the school year is when most project work is in full swing. To counter this issue, the TCROV team has, under the supervision of adults, experimented with using their ROVs under the ice. Figure 10 shows a specially designed (to be small and maneuverable) ROV being launched through an augured opening.
The team has now developed safe protocols for using ROVs under the ice and has captured some fascinating video. These observations, like those of the zebra mussels described above, have led to many questions which the team is interested in exploring. For example, students have observed plant material scattered, sometimes densely, about the underside of the ice roof. They have questions such as; what species of plant(s) are represented, how the material migrates to the ice roof, and what happens to it over the winter and into spring?

More information about this team’s work is presented on the HSE website: http://www.enterprise.mtu.edu/highschool/currentteams/traverse-city-central/index.html. The team also posts many videos on its own Vimeo pages: http://vimeo.com/user1446488/videos

Summary and Conclusions
This paper has focused on one HSE team using ROVs to excite and motivate students to continue study in STEM. This program started with an emphasis on the MATE competition but over time devoted more time and resources into general aquatic studies. This shift in focus has continued to the point where now competitions are just a small part of the teams overall mission. This results in the students gaining more “Voice and Choice” in what and how they will learn. This example can serve as a model to other student groups who up until now have been concentrating on competition ROVs, but are ready explore new educational territory. University partners can play a large role in helping facilitate this shift. Specifically, three ways in which a university can help are:

1. Sponsor and/or conduct teacher workshops on the building and use of light duty ROVs for education. These can be held on the college campus or elsewhere.

2. Identify schools or other organizations that participate in MATE ROV competitions. Encourage and support them to expand their program to include independent research and development. Search for MATE competitions close to your location and contact participating schools to see about partnering with them. It is often easy to identify mutually beneficial partnering opportunities when each party learns about the other’s goals and mission.

3. Recruit high school teacher/s to coach team-based ROV projects and support them with funds, mentoring (from faculty and/or students), technical help, supplies, team building, etc.

There are many potential funding sources to support these efforts. Some examples include:

- outreach funds in research grants
  - State specific (NASA) Space Grant Consortia
  - Government, corporate or private foundations with missions to foster STEM education
  - Industry groups with interest in Ocean and Marine education, outreach and workforce development
  - Individual corporations and businesses located near the ROV team
  - Parent groups such as academic booster clubs within the community or school system
Individuals or organizations interested in pursuing any of the above are encouraged to contact the author for further information and discussion.

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