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Back to the top

Accomplishments

* What are the major goals of the project?

The information included within this report covers the period from July 1, 2015 through June 30, 2016.

Our ITEST Scale-Up project, *Scaling up Success: Using MATE's ROV Competitions to Build a Collaborative Learning Community that Fuels the Ocean STEM Workforce Pipeline*, expands the best practices that we identified, based on evaluation data and regional reporting, as most effective in reaching, engaging, and supporting student and teacher participation in STEM. The project's overarching goal is to encourage multi-year student participation in an effort to deepen student interest and learning and reinforce pathways leading to the STEM workforce. Our hypothesis is that for each additional year a student participates in engineering design challenges

such as the MATE ROV competition, their likelihood of going to college increases, their likelihood of declaring a STEM major increases, and their likelihood of entering the STEM workforce increases. The following four goals (and the activities described beneath each) provide the foundation for our work:

1. Increase middle and high school students' interest in STEM and STEM careers as well as their knowledge of STEM and understanding of how science and engineering work together to solve real-world problems.

1a. Add a SCOUT+ competition class so students can gradually step up their knowledge and skills.

1b. Create a support system for students who move on to the next grade and find there are no robotics activities.

1c. Provide opportunities for students to interact with working professionals as well as student mentors to support their learning and provide examples of STEM careers.

1d. Document and share inspirational stories of successful students and working professionals to help students visualize themselves in pathways to STEM careers.

2. Provide teachers with professional development, instructional resources, and mentors to support and sustain the delivery of STEM learning experiences and career information.

2a. Develop a continuum of curriculum that is tied to the Next Generation Science Standards (NGSS) and includes online complementary resources.

2b. Develop a progression of ROV "kits" that complement the curriculum.

2c. Designate regional teacher "leaders."

2d. Offer week-long professional development workshops focused on the curriculum and kits.

2e. Offer regional professional development and student-focused workshops.

2f. Increase preparedness of near-to-peer student and industry mentors.

3. Increase parental involvement in order to support and encourage students to pursue STEM education and careers.

3a. Create an online parents' resource center and listserve.

3b. Form regional parental advisory committees that provide feedback and advice.

4. Track students longitudinally to document how participation impacts their education and career path.

4a. Improve our current student tracking system.

4b. Use the videos described under Goal 1d to document student education and career pathways.

The evaluation report for this grant year is included within the supplemental documents.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities:

1a. Add a NAVIGATOR (SCOUT+) competition class. Fifteen of the 18 U.S.-based regional competition programs received ITEST funding this year: Carolina, Florida, the Great Lakes, the Mid-Atlantic, Monterey, New England, Northern Gulf Coast, Oahu, Ohio, Oregon, Pennsylvania, the Pacific Northwest, Shedd Midwest, Southeast, and Wisconsin. Seven of those regionals offered a NAVIGATOR class (four regionals offered a NAVIGATOR class in Year 3); all seven plan to offer it again in Year 4. Two regionals are thinking about adding it next year. The remaining six regionals reported that they did not (and do not plan to) offer it because currently there is no demand.

1b. Create a support system for students. Students and parents looking to start or continue with the ROV competition were connected with the following resources: 1) the regional coordinator nearest them; 2) MATE's bank of online instructional materials, including building instructions, curriculum modules, how-to videos, and technical reports from previous competitions; 3) the MATE store for access to ROV kits, practice boards, and more; and 4) access to MATE's online forums, which include a technical help and competition FAQs board. While no formal survey was conducted this year to assess user satisfaction and usage of the online resources, comments shared via post-competition surveys indicate that parents found the resources to be helpful. (See the Year 3 Evaluation Report for further details.)

1c. Provide opportunities for students to interact with mentors. Nine of the 15 regionals that participated in ITEST reported connecting teams with mentors. The mentors were industry professionals; high school, community college, university, or graduate students; or teams mentoring other teams. Regionals facilitated connections in creative ways; for example, one hosted an "Ask an Expert" class and a "Virtual Engineer Mentor" unit, and connected middle school teams with the high schools that their students feed into to help make the transition a smooth one. Another engaged returning competition students to mentor teachers starting new teams. Many of the coordinators of the regionals that did not explicitly report connecting teams with mentors served as mentors themselves. All 15 regionals utilized industry professionals as judges during the competition events.

1d. Document and share inspirational stories. Links to five video interviews with students collected during the 2015 international competition are posted here www.marinetech.org/gallery/ (the videos themselves are posted on both MATE's

YouTube and Vimeo Channels). During their interviews, the students discuss their experience with the competition and their future education and career goals, among other topics. Student "stories" are also showcased in the 2016 MATE Monterey Bay regional summary video that is also located on that page (you can also find it directly by visiting https://vimeo.com/170548699). The final (middle school) student comment is particularly insightful:

So [the competition] really helps you learn about the scientific process and stuff that's probably gonna come in handy later in life in internships, jobs, and even in pioneering new innovations and helping the world.

Footage collected during the 2016 international ROV competition is currently being compiled a summary video highlighting the event. This video will be released later this fall.

In addition to these videos, the story of the Stockbridge High School ROV team was featured in a "reality TV" entrepreneurial video series. The series, produced by Pellet Productions, was funded through Kingsborough Community College's NSF Advanced Technological Education (ATE) grant.

2a, 2d, and 2e. See **What opportunities for training and professional development has the project provided?**

2b. Develop a progression of ROV kits. In the fall of 2015 we introduced one new ROV kit (an enhanced TriggerFish with digital controls) and brought back, by popular demand, an improved version of the AngelFish, the first ROV kit that we developed. We now offer four ROV kits to support a progression of learning: 1) AngelFish (simple electronics); 2) PufferFish (simple-intermediate electronics); 3) TriggerFish-Analog (intermediate electronics); and 4) TriggerFish-Digital with microcontrollers (intermediate electronics with computer programming). A description of these ROV kits can be found here http://www.marinetech.org/store/.

We provided (at no cost) more than 150 ROV kits along with lab kits, textbooks and building supplies to the regionals that participated in ITEST activities in Year 3 to support their teacher workshops. In addition to the kits provided through ITEST, we have sold an additional 857 ROV kits this past year. Schools, camps, museums, and parents across the country are also buying kits directly from us.

A great deal of time and testing has gone into the development of the kits, not only to enhance the learning experience, but to maximize production efficiency. We continue to update and improve these kits with new versions, but the foundational technology, along with the product names, will continue to remain the same for the foreseeable future.

The four kits support the student learning objectives outlined in the MATE Underwater Robotics student learning outcomes document http://www.marinetech.org/files/marine/files/Curriculum/PufferFish/MATE%20UWRob

otics%20Learning%20Objectives.pdf. These learning objectives provide knowledge and skills in engineering design (aligned with the Next Generation of Science Standards) along with electrical, mechanical, physical science, and computer science knowledge and skills. These knowledge areas are foundational to a variety of robotics and automation that are critical to every sector of the U.S. economy. The ROV design and building experience, coupled with the comprehensive competition experience, produces well-rounded students that are conversant in project management (including managing failure), teamwork, communication (oral and written), leadership, entrepreneurship, and the application of technology and science to solve real-world problems.

In addition to ROV kits and textbooks, we offer a variety of other materials, such as camera waterproofing kits, sensor kits, lab packs, and replacement parts for all of our ROVs, through our SeaMATE store. Since last fall, we have devoted considerable time and effort to scaling our store operations. For example, efficient inventory and quality control procedures were developed and implemented to support the growth of the store. This next year, we will focus on enhancing the online ordering experience for customers.

One of the major barriers to participation, outlined in last year's I-Corps for Learning study, was lack of access to easy-to-order materials from a single vendor that would accept school purchase orders. We will continue to work on increasing the ease of access and will continue to add innovative materials to our product line. For example, we will start offering school competition kits this fall.

2c. Designate regional teacher "leaders." Ten of the 15 regionals participating in ITEST had at least one local teacher leader; several had more than one. These teacher leaders led or assisted with professional development workshops and student outreach; mentored other teachers in starting ROV programs at their schools; connected teachers and students with industry and student mentors; helped teams decipher the MATE competition manuals and fielded questions about participating in the event; presented at conferences and workshops; and/or participated on regional advisory committees. We will continue to encourage regional coordinators to utilize teachers experienced with ROV design and building and the MATE competition as resources for themselves and other teachers in their regions.

(Continued under Key Outcomes or Other Achievements)

Specific Objectives:

See **What are the major goals of the project?** above.

Significant Results:

Over the course of Grant Year 3, our project:

- Supported 15 regionals with ITEST funds.

- Held a regional coordinators meeting where 21 coordinators representing 19 regions attended in person, with 3 additional coordinators (one representing a 20th region) attended via teleconference.
- Offered a NAVIGATOR competition class in 7 regions.
- Continued progress towards creating a multi-year student support system that consists of professional development instructional resources, mentors, parents, and more. However, we did not reach our stated goal to improve multi-year competition participation by 5% each year; the percentage of multi-year students actually declined slightly from one year to the next.

    - We see this as a result of the overall growth of the competition. As the competition network continues to expand, by definition, it draws in new, first-time competitors. For example, between Year 1 and Year 2, we added 1 new regional and between Year 2 and Year 3, we added 3 new regional programs. So, while the percentage of multi-year students declined slightly from Year 1 to Year 2 (42% in Year 1 vs. 40% in Year 2), the number of multi-year students increased from 1,345 to 1,537, an increase of 14%. And, while the percentage of multi-year students declined slightly from Year 2 to Year 3 (40% in Year 2 vs. 38% in Year 3), the number of multi-year students increased from 1,537 to 2,016, an increase of 32%.

    - We propose to redefine our goal to look at the overall change in the number of multi-year participants from year to year. See **Changes in approach and reason for change** for additional information.

    - *Note: This year, we used registration data, rather than post-competition surveys, for these numbers because registration data is more comprehensive (i.e., more students register via the Active system than complete post-competition surveys).
- In our analysis of post-competition surveys, we did find several statistically significant differences between the first year and multi-year competition participants. For example, multi-year participants reported that their participation in the ROV program resulted in higher levels of awareness of and interest in STEM careers, gains in interest in taking STEM courses, improvements in STEM knowledge and skills, increased 21st Century skills, and the receipt of awards, honors, and new educational and career opportunities.
- Provided students with access to student and industry mentors in 9 regions.
- Produced a summary video highlighting the 2015 international ROV competition (see https://vimeo.com/161073555) as well as five videos of student interviews captured during the event. In addition, collected footage during the 2016 international competition that is currently being compiled into a video highlighting that event.
- Was invited by the White House Office of Science and Technology Policy to submit student success stories for consideration for the 2016 White House Science Fair. AMNO & CO, an ITEST grant success story, was selected to participate. PI Jill Zande and the students' parents escorted the team to the White House, where they met the President and demonstrated their ROV in a tank staged in the East Garden. [See the attached "Student Description Input 2016_MATE underwater robotics competition."]

- Offered 4 ROV kits that complement MATE instructional resources as well as other building materials and resources (e.g., soldering practice board).
- Ten regions utilized teacher leaders as resources for coordinators and other teachers. Several of these regions had more than one teacher leader.
- Offered 1 workshop that provided 60 hours of professional development to 20 participants.
- Offered 27 regional professional development workshops that provided an average of 11 hours of instruction to more than 460 teachers. Taking into account the teachers' participation in student workshops, such as pool practice days, and competition events, and the number of hours increases to more than 30.
- Offered more than 260 regional workshops, such as topic-specific hands-on instruction, information sessions, and pool practice days, that engaged more than 6,300 students, 1,029 in an after school setting, 3,483 during school, and 1,825 as part of a community organization or event.
- Provided mentors with access to information and resources to support their role in the classroom and streamline communication. Ninety-six percent of the teachers who responded to post-competition surveys that a mentor came to their site to help their teams (N= 89) indicated that their mentors were adequately prepared to help them and their students through the ROV design and building process.
- Surveyed 440 parents attending competition events and engaged 35 as members of regional advisory committees. Fifty parents participated in regional professional development workshops; countless others attended community-wide events where regional partners exhibited. In addition, directed parents to our online resources and invited them to join our e-mail listserves to support their involvement and improve communication.
- One hundred twenty-six organizations, 304 industry professionals, and 102 others (e.g. community members) supported the grant activities. The activities were also supported by 51 high school, 22 community college, 67 university undergraduate, and 14 graduate students as well as 5 community college and 29 university faculty members.
- Benefitted from the guidance and oversight of 12 regional advisory committees (that include, among other members, a total of 35 parents).
- Eight regionals held advisory committee meetings either in-person or via teleconference call or webinar; regions that did not hold formal meetings collaborated with members in smaller groups or used a tool (e.g. Survey Monkey) to survey their members for feedback.
- Continued to use Active to collect both team and student competition registration information. Used this data, along with post-competition surveys, to help us to determine 1) how many students were involved for multiple years and 2) how their long-term participation influenced their interest in pursuing STEM courses and careers.
- Surveyed competition "alumni" to measure the impact of the competition on their education and career. Four hundred thirty-two student alumni over the age of 18 completed the survey.
- Continued to improve the utility of MATE web resources and used social networking tools to increase communication and collaboration. For example, we posted weekly to the competition FB page; this increased to continuous, multiple postings during the 2016

international ROV competition. On July 27, 2016 this page had 4,834 "likes," an increase of more than 1,200 "likes" from the same time last year.

- Maintained a live videostream from the NASA Johnson Space Center's Neutral Buoyancy Lab during the 2016 international competition (see www.marinetech.org/live-videostream/ for the page set-up) and used three Twitter (#2016MATE, #NASANBL, and #2016MATElivestream) to communicate with the public; these hashtags were referenced in a total of 363 tweets. We also livestreamed the entire awards ceremony (see our competition FB page for a recording). In addition, OpenROV supported the event by livestreaming video from a secondary pool location (see https://www.youtube.com/watch?v=Gvp5R0p9fWM for a recording of the stream). Co-founded by former MATE competitor Eric Stackpole, OpenROV is a company that manufactures a low-cost, open source ROV for exploration. In addition to Eric, the company employs other former MATE competition students.
- Disseminated information about the ROV competition program via 100+ publications and more than 70 conferences, meeting, and workshops, including a briefing to the House of Representatives Ocean Caucus organized by the Marine Technology Society. The briefing included representatives from Shell and the XPrize.
- Used surveys and other instruments to evaluate progress and increase effectiveness and impact.

Key outcomes or Other achievements:

(Continued from Major Activities)

2f. Increase preparedness of student and industry mentors. Regional coordinators continued to engage high school, undergraduate, and graduate students as well as community college and university faculty, industry professionals, and community members as mentors and volunteers at workshops and competition events. Nearly 600 students, faculty, industry professionals, and community members supported grant activities this year.

Through the regional coordinators, mentors also had access to the information and training modules reported in Year 1 as well as the online resources described under "**What was accomplished under these goals?" 1b**. Based on comments from post-competition surveys, users found these resources helpful.

The results of the 2016 post-competition teacher survey speak to mentor preparedness. For 26% of the post-competition teacher survey respondents (N=339), a classroom/club mentor came to their site to help their teams. Among these teachers, the mentor helped them incorporate robotics into their course or club to a "great" or "moderate extent" for 87% of the respondents. The majority of those teachers (96%) indicated that their mentors were adequately prepared to help them and their students through the ROV design and building process.

3a. Create an online parents' resource center. The Parent Resource Center page is located within the competition section of the MATE web site (see

www.marinetech.org/parent-resource-center/). The resource center includes a "welcome" note targeted to parents as well as links to information and resources. It also includes links to the "Gallery" page that contains videos from the international and regional competitions. (Note that these are resources that also support students, teachers, and industry mentors seeking information on how to participate, so many are also found on other pages of the MATE web site.) A document with highlights of 2015 evaluation data that demonstrate the positive impact of the program is also located on the resource center; a document with highlights of the 2016 evaluation data will be added in August.

Comments included on post-competition surveys indicate that parents found the online resources helpful. For example:

Great overall experience, I have no experience with ROV's but the MATE educational PowerPoints really helped!

3b. Form regional parental advisory committees. Twelve of the regions participating in Year 3 ITEST have advisory committees. Eight of those include at least one parent; six of those eight include two or more parents. The majority of the advisory committees grew out of the stakeholders' meetings that each regional was encouraged to hold prior to developing their plan of activities; these committees include industry members, parents, teachers, and/or students. Eight regionals held advisory committee meetings either in-person or via teleconference call or webinar; regions that did not hold formal meetings collaborated with members in smaller groups or used a tool (e.g. Survey Monkey) to survey their members for feedback. We will continue to encourage all regional coordinators to assemble advisory committees and to utilize these committees for guidance and feedback on regional activities.

4a. Improve our current student tracking system. Again this year we used Active, a low-cost, commercially available system, to collect both team and student competition registration information. We used the student registration data to determine that 38% of the student registrants had competed for multiple years.

See the Year 3 Evaluation Report for further details; also see **Changes in approach and reason for change** as well as **Actual or Anticipated problems or delays and actions or plans to resolve them** for information on how we are using this data in our work with the and the National Student Clearinghouse Washington State Education Research Data Center.

4b. Use the videos described under 1d. See 1d above.

* What opportunities for training and professional development has the project provided?

2a. Develop a continuum of curriculum. We restructured based on findings from our I-Corps for Learning experience and will continue to develop professional development opportunities

and curriculum resources with these findings in mind. (Please see the Year 2 annual report for details.)

Finding an affordable and user-friendly course management system (CMS) has been a barrier to expanding our professional development offerings, delivering curriculum resources in a way that educators can modify and expand upon while we can closely monitor, and administrating pre- and post-tests in a systematic way that meets the teachers' needs, not just ours. We have been hosting the Moodle CMS on our servers in the past, but it was not easily transferable to other schools and was, at times, painfully slow.

We are currently testing Canvas by Instructure. It is fast, user-friendly, 100% on the Cloud, and integrates well with Google Docs. Best of all, we can easily clone courses for other educators on the Cloud, and they do not need any special software or licenses, simply internet access. In this way, we can develop a course (i.e., a collection of curriculum resources) with assessments (e.g., quizzes) transfer it to another educator, let him/her modify it to suit his/her needs (which is critical to adoption and implementation), and collect pre- and post- data from tests that are adapted from our assessments. We can also learn more about the educator's needs and interest by the way he/she adapts, modifies, and implements the course.

In 2016 about 75% of our summer institute teachers reported that they use the internet in their classrooms. Chromebooks continue to increase in popularity; Cloud-based software and applications are becoming the standard. Providing access to MATE curriculum resources in the way that teachers use and deliver their curriculum is key to ensuring that MATE resources are used and adapted for the classroom. Canvas will allow us to do that.

We will be selecting teachers from our 2016 Summer Institutes to pilot our curriculum resources and assessments that include pre- and post-tests delivered within the Canvas CMS so we can deliver, monitor, and assess the effectiveness of the materials and procedures on student learning. We will be working closely with Dr. Min Li in designing, piloting, and assessing the psychometric quality for the pre- and post- tests.

2d. Offer week-long professional development workshops. The sixth annual ITEST Summer Institute, *Introductory Level ROV Building: The PufferFish ROV*, took place July 26 –August 2, 2015 at MPC. This institute introduced participants to the PufferFish ROV. Participants learned the fundamentals of engineering design, project management and ROV building and experienced a variety of hands-on science, technology, and engineering activities that can be integrated into a class or afterschool activity to reinforce foundational knowledge and skills. Along with MATE staff, two engineers (one mechanical, one electrical) co-taught the institute to ensure that best engineering design practices were applied to all building activities; the instruction followed the format of the NGSS for engineering.

Instructional materials from this institute can be found here www.marinetech.org/pufferfish-rov-curriculum/. All 20 participants (17 teachers and three informal educators) rated the usefulness of the workshop as excellent.

The next PufferFish summer institute took place July 10 – July 17, 2016; 20 teachers and informal educators participated. Additional details about this institute will be reported in the Year 4 annual report.

We offered the online workshop *Diving into Underwater Sensors and Arduino* for the second year. Forty-two participants enrolled in this 30-hour course that covers the hardware and software development environments for sensor interface and programming. After learning the basics of Arduino programming, the participants build and collect digital data from six sensors commonly used in the underwater environment. See www.marinetech.org/files/marine/files/Workshops/Diving%20into%20Sensors%20Course%20Outline.pdf for the course outline.

The goal of this course is to provide a foundation for the hardware and software required to migrate to the digital TriggerFish ROV. This course was inspired and designed based upon feedback from workshop participants on new skills and information they would like to learn from both our ITEST and ATE grant-funded work. This course is funded with program income generated from the SeaMATE store sales.

This next year we plan to expand our online course offerings to provide more teachers with high quality professional development experiences. Specifically, we are looking at offering more of the content from our summer institutes in an online format so we can reach more teachers.

2e. Offer regional workshops. Fourteen of the 15 regions that participated in ITEST and reported their data offered professional development for teachers. A total of 27 professional development workshops were offered to 464 teachers; the following is a breakdown by grade level:

Grade 3-5: 83; Grade 6-8: 142; Grade 9-12: 155; postsecondary: 8; Informal educators: 27; Other (e.g. parents): 49

The workshops ranged from ½-day ROV design and building activities (where the focus was on frame design, motor placement, and buoyancy) to multi-day events (where the focus was building control boxes). The number of hours of instruction for each teacher ranged from 3 to 35; the average was nearly 11. The workshops were offered during school, after school, on weekends, in the evening, and/or during the summer.

Fourteen of the 15 regions that participated in ITEST and reported their data also offered workshops focused on students. All total, 263 workshops were offered to 6,337 students. Of these students, 3,483 were impacted in an in-school setting, while 1,825 and 1,029 were impacted as part of a community organization or event or in an after school setting, respectively. The following is a breakdown by grade level:

Grade 3-5: 2,516; Grade 6-8: 1,560; Grade 9-12: 1,225; postsecondary: 47; Other (e.g. home school not defined by grade level or community event where grade levels are not known): 989

The workshops covered topics from basic ROV design and building to simple electronics and AngelFish and PufferFish ROV kit assembly. Information sessions, pool practice days, and "demo nights," among others, were also offered. The number of individual student contact hours ranged from 1 to 40; the average nearly 10.

Fourteen of the 15 regions that participated in ITEST reported that they used MATE's ROV kits and/or practice boards as the focus of their workshops; all of these regions reported that the kits were helpful. One region offered a suggestion for improving the TriggerFish assembly instructions; another noted that it is "tough for people new to the web site to access some of the resources, and some of the curriculum resource labels are not easy to figure out." These suggestions and concerns will be addressed in Year 4. Regions that used the AngelFish indicated that they like the kit's simplicity and reusability. Twelve regions reported that they used MATE's on-line curriculum or videos; and 13 used the instructions for kit assembly. Ten indicated that they used the MATE textbook as a resource for themselves and their teachers.

Comments from regional coordinators about the support they received from MATE included:

[The kits} allowed teachers an easy jumping off point to get involved without sourcing the materials themselves. – Oahu regional coordinator

We find the practice boards to be very helpful in teaching teachers how to solder prior to working with the kits. They have an opportunity to gain experience and confidence, which is extremely important for many of our middle school teachers. – New England regional coordinator

* How have the results been disseminated to communities of interest?

Between the MATE Center, its regional partners, and ROV competition participants, more than 100 abstracts, journal papers, newspaper articles, web sites, television news stories, and other publications featured ITEST grant activities. Examples of these are included within the products section of this report.

In addition, between the MATE Center and its regional partners, information about the ITEST project was presented at more than 70 conferences, meetings, community events, workshops, and other events. These included the following:

- National Marine Educators Association Conference, held June 29 – July 2, 2015 in Newport, RI.

- Wisconsin Space Grant Consortium Conference, August 14, 2015.

- FabLearn, Conference on Creativity and Fabrication in Education, held September 26-27, 2015 at Stanford University.

- Southeastern Massachusetts Connect – Envision the Future Conference, November 10, 2015.

- Connecticut Science Teachers' Association Conference, November 21, 2015.

- Northwest Michigan Robotics Conference, December 2015.

- Underwater Intervention Conference and Exhibition, organized by the Marine Technology Society's ROV Committee and the Association of Diving Contractors International and held February 23-25, 2016 in New Orleans, LA.

- Philadelphia Science Festival, April 30, 2016.

* What do you plan to do during the next reporting period to accomplish the goals?

During the next reporting period (Grant Year 4) we will:

- Support 15 or more regional partners with ITEST funds.

- Hold a regional coordinators meeting to build community and increase regional fidelity, among other goals.

- Continue to add a NAVIGATOR competition class to regionals, based on the regional demand and feedback from stakeholders.

- Compare Year 3 to Year 4 to determine 1) if we have improved multi-year competition participation by 5% (and, if not, dive deeper into the data to interpret why) and 2) what other statistically significant gains multi-year participants have made compared to first-year participants.

- Continue to provide students with access to student and industry mentors who are well-prepared to support learning and provide career guidance.

- Document 2-4 student success stories and collect and share at least five student interviews for evaluation purposes.

- Test cloning (producing copies of) the PufferFish Summer Institute course in the Canvas content management system so that educators can adapt and deliver the content directly to their students in a way that best meets their needs. We plan to enhance the course with new instructional videos. In addition, each module will have pre and post-test questions to assess student learning. We will work with Dr. Min Li to develop these tests.

- Continue to improve our ROV kits (we will be releasing version 6 of the PufferFish and version 3 of the TriggerFish in September 2016) and continue to create additional materials to enhance student learning. For example, we plan to introduce an in-school competition kit this fall.

- Continue to encourage MATE regionals to identify and utilize regional teacher leaders to function as resources for coordinators and other teachers.

- Offer 1 workshop that provides 60 hours of professional development to at least 20 participants, including middle and high school teachers and regional coordinators.

- Offer at least 20 regional professional development workshops that provide 10 or more hours of instruction to 300 teachers.

- Offer an additional 100 regional workshops, such as topic-specific hands-on instruction, information sessions, and pool practice days, to 600+ students.

- Work with regional coordinators to add to the current mentor information and training to support their role in the classroom and streamline communication.

- Continue to engage and increase the number of parents in grant activities and continue to add to the resources and information included with the Parent Resource Center. Direct parents to our online resources and invite them to join our e-mail listserves to support their involvement and improve communication.

- Increase the number of organizations, industry professionals, and others as well as high school, community college, university undergraduate, and graduate students and community college and university faculty supporting the grant activities.

- Continue to encourage regionals to create and meet with regional advisory committees to provide guidance and oversight.

- Use the student competition registration system in conjunction with the post-competition surveys to determine 1) how many students are involved for multiple years and 2) how their long-term participation influences their interest in pursuing STEM courses and careers.

- Improve the organization and utility of MATE web resources and continue to use social networking tools to increase communication and collaboration. This will include increasing the use of Twitter.

- Use surveys and other instruments to evaluate progress and increase effectiveness and impact.

Please also see the **Major Activities, Key Outcomes or Other achievements,** and the **What opportunities for training and professional development has the project provided?** sections.

Products

Other Products

- *Data and Research Materials (e.g. Cell lines, DNA probes, Animal models).*

  NOTE: The Year 3 evaluation report is included within the Supplemental Documents.

  1. During negotiation, additional information was requested regarding the data management plan to ensure how products of the research (reports, instruments, and data) would be made accessible to other researchers.

  Action 2D: Please what was accomplished during Year 3 pertaining to the work you proposed in your responses, including:

  - sharing of evaluation reports, evaluation instruments, de-identified data sets, and website analytics at the project website and ITEST's STEM Learning Resource Center.

  If the goals/objectives were not fully accomplished during Year 3, please include what changes will be made to your plan and timeline to achieve these goals/objectives.

  Our Years 1 and 2 annual and evaluation reports have been submitted to STELAR; our 2014-2015 post-competition survey instruments have been posted to our project's page on ITEST STELAR web site.

  The web page http://www.marinetech.org/itest currently contains project and evaluation reports from our ITEST Strategies work and Years 1-3 of our ITEST Scale-Up. The 2014-2016 survey instruments, 2014-2016 survey results, and information on how to obtain datasets and web site analytics data are also included there. Visitors to the MATE web site can find instructions on how to access this information on the "about MATE" page (see http://www.marinetech.org/about/); once they have created a login, they can access the information.

What other collaborators or contacts have been involved?

The MATE regional competition network includes programs in Canada, Hong Kong, Scotland/UK, Russia, Egypt, and Turkey. While the organizations that coordinate MATE programs in these regions do not benefit directly from ITEST grant funds, they do leverage the ITEST-supported activities and products. They also share their best practices and lessons learned with the competition network. These organizations (and the points of contact at each) are listed below:

Dwight Howse and Paul Brett, Marine Institute of Memorial University of Newfoundland and Labrador, St. John's, NL, Canada

Mike Duggan and Peter Oster, Nova Scotia Community College, Halifax, NS, Canada

Robin Bradbeer and Paul Hogan, Pearl Technologies, Ltd., Hong Kong

Graeme Dunbar, John Still, David Howie, and Steve Allardyce, The Robert Gordon University, Aberdeen, Scotland

Sergey Mun, The Center for Robotics Development, Maritime State University, Vladivostok, Russia

Mahmoud Abdel Aziz, Hadath for Innovation and Entrepreneurship, Cairo, Egypt

Dr. Ihab El-Aff, EngTechs Engineering & Technology, Izmir, Turkey

Back to the top

Impacts

What is the impact on the development of the principal discipline(s) of the project?

A number of prior reports have identified significant problems in educating, recruiting, and retaining U.S. workers for scientific, technological, and operational careers. Such workers are critical for building and operating much of the nation's infrastructure and for sustaining growth and innovation. The lack of appropriately educated workers is especially pronounced in ocean fields, such as deep water ocean exploration; the engineering of specialized tools and instruments for remote, harsh environments; and the management and use of ocean resources (particularly, renewable resources). The graying trend in the marine workforce adds to the urgency of educating new technical professionals that will adapt and excel in the rapidly advancing ocean workplace.

Workforce studies previously conducted by the MATE Center and funded by the Office of Naval Research identified more than twenty STEM-based ocean occupations that are currently limiting the growth of ocean industries because of the lack of qualified personal. At the top of the list are the following occupations: electronics/marine technicians; engineers (electrical, mechanical, civil/structural); and computer scientists (software application developers, computer programmers, hardware developers).

However, these are not “just” engineers, technicians, and computer scientists; these are professionals that understand ocean applications within their field. For example, ROV technicians in support of ocean operations must have an understanding of ocean science in addition to engineering and computer science since all commercial ROVs possess computer-controlled systems and must be maintained, repaired, and modified in remote locations far from port. These skills sets are transferable to almost every sector of the economy that uses robotics, automation, and computer-controlled systems.

Every year, the ocean attracts thousands of students to pursue degrees in biology because that is a discipline that most students associate with ocean careers. However, the opportunity and compensation in ocean-related engineering, technology, and computer science fields is much greater than the biological sciences. Combining STEM education with ocean applications via the

MATE ROV competition network provides students with a pathway to achieve their goals, including the gainful employment that is so critical to engaging students from economically disadvantaged environments. For the ocean occupations in greatest need of qualified individuals, the early education and career preparation is similar. This includes applied math, critical and creative thinking, and design and innovation, which, during the competitions, are presented in an engaging environment that simulates the high-performance workplace.

What is the impact on other disciplines?

Covered above under "What is the impact on the development of the principal discipline(s) of the project?"

What is the impact on the development of human resources?

The work of this project supports the development of a diverse ocean STEM workforce, outlining and allowing students to see a career pathway from upper elementary school to middle and high school to college and into the workplace. It is also providing valuable workplace experience; all of the ROV kits funded by this grant are assembled, packaged, and shipped by community college students (Please see the ACCOMPLISHMENTS section for details.)

The findings of the alumni survey demonstrate the impact on workforce development. This survey, which was launched in June 2015, gathered data on students' education and employment. Four hundred thirty-two student alumni responded. A sampling of results is presented below; for additional details, please see the Year 3 Evaluation Report.

- Among the 220 alumni who earned a college degree, 85% earned a degree in a STEM discipline.
- Among the 236 current college and university students, 85% are studying towards a STEM degree.
- Among the employed alumni (N=320), 73% are currently working a STEM-related job, and 22% currently or previously worked a job related to ROVs or other underwater technologies.
- Two-thirds (67%, N=432) of the alumni credit the ROV competition with influencing their educational or career path "to a great extent" or "somewhat".
- The ROV competition played a role in alumni attaining employment (37%), admittance into educational programs/college/university (36%), internships (30%), awards (21%), and scholarships (21%).

What is the impact on physical resources that form infrastructure?

Progress on the MATE workshop continued, with additional space secured for inventory, all of which improved the working environment for the community college students who assemble the MATE ROV kits (see the "MATE store" referenced in ACCOMPLISHMENTS).

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

Nothing to report.

What is the impact on technology transfer?

The MATE ROV kits are sold through our SeaMATE online store (http://www.marinetech.org/store/). In addition to the kits provided through ITEST, schools, camps, museums, and parents across the country are also buying kits directly from us; from July 2015 to July 2016, we sold more than $350,000 worth of ROV related items (ROV kits, textbooks, and ROV supplies). This includes 857 ROV kits (all models) and 253 textbooks. Approximately $55,000 of these sales is directly related to instructional supplies purchased in conjunction with our workshops.

Since the release of our underwater robotics textbook in 2010, we have sold more than $924,000 worth of ROV kits and related materials.

What is the impact on society beyond science and technology?

Through the impacts described under ACCOMPLISHMENTS, the work of this project is helping to prepare and create a more scientific- and technology-literate society.

Please also see the Leveraging ITEST Activities/Funding, Using ROVs Outside the Competition, Broader Impacts on Teachers and Institutions sections of the Year 3 Evaluation Report.

Back to the top

Changes/Problems

Changes in approach and reason for change

In our grant proposal, we set a goal to improve multi-year participation (as a percentage of total students) by 5% a year over the duration of the grant. After three years of evaluating the data, we realize that the way that we defined that goal did not take into consideration the full picture. As the competition network continues to expand, by definition, it draws in new, first-time competitors. For example, between Year 1 and Year 2, we added 1 new regional program and between Year 2 and Year 3, we added 3 new regional programs. So, while the percentage of multi-year students declined slightly from Year 1 to Year 2 (42% in Year 1 vs. 40% in Year 2), the number of multi-year students increased from 1,345 to 1,537, an increase of 14%. And, while the percentage of multi-year students declined slightly from Year 2 to Year 3 (40% in Year 2 vs. 38% in Year 3), the number of multi-year students increased from 1,537 to 2,016, an increase of 32%.

So, we are proposing a revision to that goal: that the overall number of multi-year participants will increase by at least 10% each year over the duration of the grant.

NSF's expectation is that the scope of activities will include elaborations and/or revisions that are discussed in pre-award negotiations. The Annual Report and Evaluation Report submitted do not specifically address several NSF questions/ requests and PI elaborations/revisions that were included in the pre-award negotiations.

During negotiation, additional information was requested about the mechanism by which implementation fidelity (or adaptation) of the ROV intervention across regions would be documented.

Action2B1: Please clarify what was accomplished during Year 3 pertaining to the work you proposed in your responses, including:

- conducting face-to-face observations of a subset of the regional efforts.

In Year 3 we were only able to conduct face-to-face observations of just one of the regional contest: Texas. (Note: One Co-PI attends the Pacific Northwest regional each year; the PI and other Co-PI coordinate the Monterey regional contest.) However, we did hold a regional coordinators meeting in the fall of 2015 (see below for details) as well as provide new MATE competition banners for each of our 26 regional programs.

During the Texas visit, we used the list of questions/observations developed in Grant Year 1 to assess regional fidelity. The list includes the following:

- Volunteers/Judges – How many? Training (pre event and day of briefings)? Did they see the judges' forum? Diversity of people – where do they come from?

- Missions/Props – were they built to specs, disputes?

- Safety Inspections – did the safety inspectors attend the webinar?

- Teachers – how much support before the competition, mentors, practice days, workshops?

- Students – how much time did they spend, in class, club, what was the hardest part, favorite part, learned the most, what do they wish was different?

- Parents – Did they get the information they need? What impact did this have on your child?

After Monterey, Texas is the oldest MATE regional ROV competition program and demonstrates regional fidelity and MATE "branding." As a "mature" regional, the coordinators are able to focus their efforts on enhancing the competition experience and helping their teams to improve. For example, in an effort to strengthen the performance of its winning teams at the

international event, three years ago the coordinators added technical documentation as a requirement for the participating teams. The mentors, if not the students, appear to appreciate this requirement and additional "push" it provides to their students to excel. One area where Texas (as well as other regionals) do need assistance is with score keeping; to that end, this year we will create a standard, master score sheet, complete with computational cells, to assist with score management and accuracy.

We held a regional competition coordinators' meeting at Monterey Peninsula College November 18-22, 2015. Twenty-one coordinators representing 19 regions attended in person, while three more (including one who represented a 20th region) joined via a teleconference line. The overarching goal of that meeting was to strengthen the MATE competition community as well as build capacity, since new coordinators as well as coordinators of new regions attended. During the meeting we 1) debriefed the 2015 competition season and provided a preview of 2016 mission tasks, including props; 2) shared best practices and lessons learned; 3) discussed changes and improvements for next year; and 4) provided professional development on the MATE ROV kits and curriculum materials. Our evaluator also shared the results of the 2015 competition surveys and the alumni survey results to date.

We believe that these discussions and activities, especially those that involved consensus (e.g., creating a new registration fee structure) and encouraged buy-in (e.g., determining mission tasks), will further help to build community and increase regional fidelity across the network. .

We are planning to hold another regional coordinators meeting in January 2017.

Action 2B2: Please clarify whether you have you have considered or established any mechanism for studying the artifacts from the professional development and/or competition experiences for assessing implementation across regions in the event observations were not conducted?

See Action 2B1.

Actual or Anticipated problems or delays and actions or plans to resolve them

NSF's expectation is that the scope of activities will include elaborations and/or revisions that are discussed in pre-award negotiations. The Annual Report and Evaluation Report submitted do not specifically address several NSF questions/ requests and PI elaborations/revisions that were included in the pre-award negotiations.

During negotiation, additional information was requested about the instruments and processes used to collect outcome data and the technical quality of those instruments, with the clear purpose of moving the research/evaluation beyond self-report.

Action 2A: Please clarify what was accomplished during Year 3 pertaining to the work you proposed in your responses that intended to:

- improve the internal consistency of existing surveys by adding questions and standardizing the question constructs;

In Year 3, we worked with Dr. Min Li to improve the consistency and validity of the four existing post-competition surveys: student, instructor, parent, and judge/volunteer. Please see the Methodologies section of the attached Year 3 Evaluation Report for a detailed summary of the work carried out by Dr. Li.

- compare survey data against students' NSC data to provide an additional form of survey validation;

We launched the competition alumni survey in June 2015. Please see **Significant Results**, bullet #19 for a summary and the Year 3 Evaluation Report for details and information on the results.

Please also see the Year 3 Evaluation Report for information regarding our work with the National Student Clearinghouse (NSC) and Washington State Education Research Data Center (ERDC).

- employ a process for validating competition scoring rubrics and determining and/or establishing methods for ensuring inter-rater reliability of competition scoring such that they may be used as an indicator of student learning; and

In Year 3, we continued our work with Dr. Min Li on the alignment study of competition scoring rubrics. The alignment study focuses on how the scoring (i.e. "coding") categories can be mapped back to (1) the competition manual in terms of how the students are mentored or guided and (2) the standards from the engineering proportion of the NGSS, 21st Century Skills, and College Readiness documents.

Dr. Li used the marketing display, technical documentation (report), and product (formerly sales or engineering) presentation scores that student teams received from judges during the 2015 events to investigate inter-rater reliability. The data file included the IDs of judges so that a generalizability study could be performed to examine whether judges evaluated the teams consistently or not. Please the Year 3 Evaluation Report for details from Dr. Li on the study, results, and analysis.

We revised the information presented in the 2016 competition manual and the marketing display rubric, technical documentation, and presentation rubrics based on Dr. Li's findings. We will continue to work with Dr. Li to conduct a similar alignment study on these rubrics in Year 4; again, we will revise them based on her results as well as on feedback from the judges who used them during this competition season.

In addition, in Year 4 we will conduct our validity studies to decide whether scores assigned by judges are comparable to researchers' evaluation.

Please the Methodologies section of the Year 3 Evaluation Report for a detailed summary of Dr. Li's work, results, and plans for continued analysis in Year 4.

- design, pilot, and assess psychometric quality for NGSS-aligned pre-post knowledge tests (and for the above competition scoring), with the assistance of Dr. Min Li.

Please see "What opportunities for training and professional development has the project provided?" 2a and the Year 3 Evaluation Report.

During negotiation, additional information was requested regarding other study designs that might be employed, such as interrupted time series design and/or use of state longitudinal data, to collect more reliable estimates of the average impact of the intervention.

Action 2C: Please clarify what was accomplished during Year 1 pertaining to the work you proposed in your responses, including:

- employing the "modified time series design" that included one pretest of knowledge and attitudes, several interim knowledge tests (quizzes at the end of each module), post- and follow up tests of knowledge and attitudes with possible triangulation with competition scores.

Please see "What opportunities for training and professional development has the project provided?" 2a and the Year 3 Evaluation Report.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.