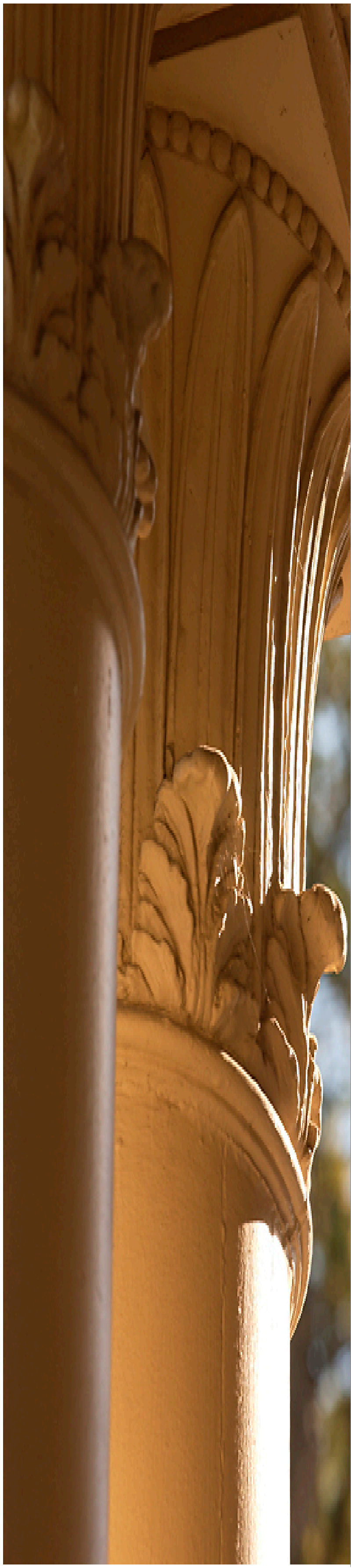

Evaluation of Innovative Technology Experiences for Students and Teachers (ITEST) 2015-2016 Grant Activities

For

The Marine Advanced Technology Education (MATE) Center

July 2016

Submitted by:

SESRC

Social & Economic Sciences Research Center (SESRC)

Puget Sound Division
Washington State University

PO Box 43170
Olympia, Washington 98504-3170
Telephone: (360) 586-9292
Fax: (360) 586-2279

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Candiya Mann and Yi Jen Wang

July 2016

WASHINGTON STATE UNIVERSITY

Social & Economic Sciences Research Center-Puget Sound Division
203 E. 4th Avenue, Suite 521
P.O. Box 43170
Olympia, WA 98504-3170
(360) 586-9292
Fax: (360) 586-2279

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ABOUT SESRC

The Social and Economic Sciences Research Center (SESRC) at Washington State University is a recognized leader in the development and conduct of survey research.

SESRC-Puget Sound Division provides technical services and consultation to assist clients in acquiring data, understanding what data means, and applying that information to solving problems. The SESRC Puget Sound Division specializes in research design, data collection and analysis, using both qualitative and quantitative methods. The Division also provides interpretive reports, policy studies, presentations and consulting services directly to individual clients, organizations and consortia.

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TABLE OF CONTENTS

TABLE OF TABLES AND FIGURES

EXECUTIVE SUMMARY

Evaluation of Innovative Technology Experiences for Students and Teachers (ITEST) Grant Activities

For the Marine Advanced Technology Education (MATE) Center

BY: CANDIYA MANN & YI JEN WANG

SOCIAL & ECONOMIC SCIENCES RESEARCH CENTER, PUGET SOUND OFFICE

WASHINGTON STATE UNIVERSITY

JULY 2016

In September 2013, the National Science Foundation (NSF) funded the Marine Advanced Technology Education (MATE) Center's proposal for an Innovative Technology Experiences for Students and Teachers (ITEST) grant. The MATE Center's ITEST program, titled *Scaling Up Success: Using MATE's ROV Competitions to Build a Collaborative Learning Community that Fuels the Ocean STEM Workforce Pipeline*, leverages their extensive network of remotely operated vehicle (ROV) student competitions. 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.

The evaluation is based on multiple data sources, primarily surveys and interviews, and reflects the input of a variety of stakeholders, including students, teachers, parents, judges, volunteers, regional coordinators, and MATE management and staff. This report covers grant activities that took place between July 1, 2015 and June 30, 2016.

Findings

Project Goal 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.

- **Increased Awareness of STEM Careers:** After building their ROV, over three-quarters of the students (79%, N=2,148) indicated that they knew more about careers in marine STEM.
- **Increased Interest in STEM Careers:** Over three-quarters (77%, N=2,149) of the students stated that their ROV project made them more interested in pursuing a STEM career, and 87% of the teachers (N=342) observed an increase in their students' interest in pursuing a STEM career. Ninety-seven percent (97%, N=342) agreed that the ROV program provided a valuable venue to help prepare their students for STEM careers.

- **Increased Interest in STEM:** Over three-quarters of the students (85%, N=2,137) indicated that their ROV project made them want to learn more about STEM. Ninety-four percent (94%) of the teachers (N=343) and 96% of the parents (N=431) observed greater interest among the students in learning STEM.
- **Increased STEM Knowledge & Skills:** The great majority of the students reported increased skills and knowledge due to their ROV project in several subjects: engineering (92%, N=2,127), technology (91%, N=2,123), the competition theme (73%, N=2,112), science (81%, N=2,131), and math (63%, N=2,118). The majority of the teachers (99%, N=342) observed improvements in their students' STEM knowledge and skills. Parents reported that building an ROV contributed to improving their children's grades in engineering/robotics (73%, N=335), science (57%, N=423), math (45%, N=421) and computers (54%, N=354).
- **Increased 21st Century Skills:** Students reported that participating in the ROV project improved their problem solving (84% agreed or strongly agreed, N=2,124), teamwork (85%, N=2,130), critical thinking (82%, N=2,119), leadership (70%, N=2,118), and organization skills (67%, N=2,113). Ninety-nine percent (99%, N=341) of the teachers observed increases in their students' skills in team building, problem solving, and/or critical thinking. Parents reported that their children were better problem solvers (95%, N=431), critical thinkers (93%, N=423), team members (96%, N=431), and/or leaders (90%, N=429).
- **Overall Rating of MATE Center Support:** After the competition season, 58% of the teachers (N=348) rated the support provided by MATE as excellent, and 35% provided a rating of good, for an overall positive rating of 93%.
- **Overall Opinions of ROV Program:** The ROV program was rated positively (excellent or good) by 89% of the students (N=2,153), 99% of the teachers (N=348) and 99% of the parents (N=430).
- **Ability to Apply STEM to Real World Problems:** In the post-competition surveys, 85% of the students (N=2,130) indicated that participating in the ROV project helped them learn to apply STEM to real world problems, and 97% of the teachers (N=343) observed improvements in their students' abilities in this area, as did 95% of the parents (N=423).
- **Ability to Communicate Engineering Process and Designs to a Wide Audience:** Eighty-one percent (81%, N=2,133) of the students stated that participating in the ROV project helped them learn how to communicate their engineering design to other people. Ninety-four percent (94 %) of the instructors (N=342) observed improvements in their students' skills in this area.
- **Influence on Students' Educational and Career Paths:** As reported in the 2014-2015 evaluation report, ROV Competition Student Alumni Survey results include the following:
    - 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%).

- **Effect of Multi-Year Competition Participation:** Multi-year participants were statistically significantly more likely to report 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.
- **Impacts among Underrepresented Groups:** According to the demographic data in the surveys (N=2,075), the students were roughly one-quarter female (29%); 40% were of minority backgrounds; 40% came from high poverty areas; and 3% reported that they had disabilities requiring accommodations. Statistically significant differences existed between the groups (gender, ethnicity, socioeconomic status, and disability status) in the following measures:
    - ***Awareness of and Interest in STEM Careers:*** Male students and students living in low poverty areas were more likely to report greater gains in interest in a STEM career.
    - ***Interest in STEM Topics:*** Male students were more likely to report increased interest in computer, math, and engineering courses. Students with disabilities were more likely to report increased interest in engineering courses.
    - ***STEM Knowledge:*** After the competition, male students and students with disabilities were more likely to report increased skills and knowledge in engineering and technology. Students living in a lower socioeconomic area were more likely to report gains in skills and knowledge in the competition theme.

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

- **Increased Confidence Facilitating STEM Learning Experiences:** The percentage of workshop survey respondents who rated themselves as "very comfortable" facilitating STEM learning experiences for students rose between the pre (N=162) and post (N=148) workshop surveys in all STEM areas: science (pre: 56%, post: 68%), technology (pre: 36%, post: 59%), engineering (pre: 29%, post: 54%), and math (pre: 42%, post: 52%).
- **The MATE Community:** Among the post-competition surveys, 80% of the teachers (N=336) agreed that they felt they were part of a MATE community that provides support and relevant resources.

- **MATE Robotics Activities/Curriculum Incorporated into Courses and Afterschool Programs:** Sixty-three percent (63%) of the post-competition teacher survey respondents (N=350) incorporated building ROVs into an after-school club. Twenty-five percent (25%) built ROVs as part of a course; 22% built ROVs as a voluntary activity; and 7% built ROVs in another venue. Over three-quarters (81%) of the competition teachers (N=312) stated that they used MATE materials and resources to incorporate ROV building into their course or club, and over half (63%) modified their curriculum and teaching based on MATE resources.
  - In the one-year follow-up survey of the week-long, intensive 2015 Pufferfish Summer Institute, 17 of the 18 participants built ROVs with students. A total of 281 ROVs were built with 1,228 students.
- **Classroom Mentors:** In several regions, the regional coordinator matched up college and high school students – in many cases, former ROV competitors themselves – with middle school ROV teams to work with them throughout the competition season. 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, over half (57%) indicated that the mentor helped them incorporate robotics into their course or club to "a great extent". Most of the respondents (96%) indicated that their mentors were adequately prepared to help them and their students through the ROV design and building process.

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

- **Increased Parental Support of Their Children's Interest in STEM:** Ninety-four percent (94%, N=425) of the parents indicated that participation in the ROV program changed how they envisioned their child's future, making it easier to picture their child with a STEM career.
- **Enhanced Online Resources:** The online Parent Resource Center was launched in the spring of 2015. It contains competition videos, frequently asked questions, background information, highlights, and contact information for the MATE Center, along with types of information that the MATE Center can provide upon request. Anecdotal feedback indicates that the parents found the resources helpful.
- **Regional Advisory Committees:** Advisory committees included participation from parents as well as industry representatives, professional organizations (e.g., Marine Technology Society), government agencies (e.g., NOAA) 6-12th grade educators, community college faculty, and university faculty. In 2015-2016, some regions held an annual advisory meeting, while others held monthly advisory meetings or communicated on an ongoing basis with advisory members outside of formal meetings. The regional coordinators were responsive to their committees' recommendations.

Conclusions

The MATE Center successfully implemented the 2015-2016 year of ITEST grant activities. The 2016 MATE ROV Competition was held, with ITEST funding helping to support 15 of the 18 US-based regional events. A total of 290 regional workshops were held for teachers and students, and 20 teachers attended the intensive (60 hour) Summer Institute professional development. The Center disseminated a suite of online instructional materials, including videos, PowerPoints, ROV kits, and an online course.

Evaluation results continue to show strong positive outcomes for students and teachers. Involvement in the ROV competition generated greater awareness of and interest in pursuing STEM careers; increased interest in studying STEM topics; improved STEM knowledge and skills; and increased teamwork, critical thinking, leadership, and problem solving skills. Participating in the ROV competition helped students learn how to apply STEM skills to real world problems. They also learned how to communicate their engineering process and design to a wide audience.

As stated in the 2014-2015 evaluation report, ROV competition student alumni survey results suggest that the majority of ROV competition participants go on to study STEM topics, earn STEM degrees, and work in STEM fields. In fact, roughly one in five former participants have worked in a job related to ROVs or other underwater technologies. The majority of ROV competition alumni credit the ROV competition with influencing their educational and career paths, including playing a role in attaining internships, scholarships, admittance to educational programs, and employment.

These findings suggest that the MATE ROV Competition is effective in increasing the STEM workforce, especially related to underwater technologies.

INTRODUCTION

In September 2013, the National Science Foundation (NSF) funded the Marine Advanced Technology Education (MATE) Center's proposal for an Innovative Technology Experiences for Students and Teachers (ITEST) grant. The MATE Center's ITEST program, titled *Scaling Up Success: Using MATE's ROV Competitions to Build a Collaborative Learning Community that Fuels the Ocean STEM Workforce Pipeline*, leveraged their extensive network of remotely operated vehicle (ROV) student competitions. 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.

As stated in the proposal, the goals are fourfold:

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.
2. Provide teachers with professional development, instructional resources, and mentors to support and sustain the delivery of STEM learning experiences and career information.
3. Increase parental involvement in order to support and encourage students to pursue STEM education and careers.
4. Track students longitudinally to document how participation impacts their education and career path.

This report covers grant activities that took place between July 1, 2015 and June 30, 2016. The MATE Center's ITEST grant evaluation was performed by the Puget Sound Division of the Social and Economic Sciences Research Center at Washington State University.

Methodology

The evaluation connects each of the project goals with evaluation questions and expected outcomes of the project. These goals and evaluation questions are presented below.

Table 1: Project Strategies and Evaluation Questions

Project Goal	**Evaluation Questions**
1. Increase middle and high school students' interest in STEM and STEM careers as well as their STEM knowledge and understanding of how science and engineering work together to solve real-world problems. • Add SCOUT+ class • Support for students who want to continue competition at next grade/school • Mentoring from students/industry professionals • Career advice/videos	1.1. To what extent did the MATE robotics activities lead to an increase in the students' interest in and knowledge of STEM content and STEM careers? Did educators and parents observe an increase in the students' interest in STEM content and STEM careers as a result of the robotics activities? An increase in the students' STEM knowledge and skills and 21^{st} Century workplace skills?
	1.2. How did the robotics activities affect students' ability to apply STEM knowledge and skills to finding solutions to real-world problems?
	1.3. How did the robotics activities affect students' ability to communicate their engineering process and designs to a wide audience (from engineers and technicians to the general public)?
	1.4. How did participation in the robotics activities influence students' educational and career paths?
	1.5. What effect did multi-year participation have on the above evaluation questions?
	1.6. Did the robotics activities create the same impacts among underrepresented groups (by gender, ethnicity, socio-economic status, disability) as were found among students who traditionally participate in these types of activities?

2. Provide teachers with professional development, instructional resources, and mentors to support and sustain the delivery of STEM career information and learning experiences. • Curriculum continuum • Progression of ROV kits • Professional development workshops • Regional workshops • Regional teacher-leaders • Increase preparedness of mentors	2.1. Are teachers more confident delivering STEM learning experiences? Delivering career information and outlining career pathways?
	2.2. Do teachers feel they are a part of a larger MATE community that provides support and relevant, necessary resources?
	2.3. Do teachers incorporate MATE robotics activities/curriculum into courses and afterschool programs? Are the courses and/or curriculum adopted by school districts?
	2.4. Are teachers able to access classroom mentors as needed? Do the classroom mentors help them successfully incorporate robotics activities into the course? Are the classroom mentors adequately prepared?
3. Increase parental involvement in order to support and encourage students to pursue STEM education and careers. • Parent online resources/listserv • Regional parent advisory committees	3.1. Did the MATE robotics activities lead to an increase in the parents' support of their children's interest in STEM careers? 3.2. Did the enhanced parent online resources lead to an increase in the parents' ability to provide assistance and support for their children's involvement in the MATE robotics activities? 3.3. Did the regional parent advisory committees provide feedback and advice to help improve the competitions and ensure that the program is inclusive of all participants?

DATA SOURCES

The evaluation relies upon multiple sources of data. The data collection includes input from a variety of stakeholders, including students, teachers, parents, judges/volunteers, regional coordinators, and MATE staff. Below are descriptions of each of the data sources. All of the surveys were developed in collaboration with MATE staff and regional coordinators.

Student Follow-up

In 2014-2015, the evaluation began several student follow-up efforts: 1) the Washington State Follow-up, 2) The ROV Competition Student Alumni Survey, and 3) the National Student Clearinghouse Data Match.

WASHINGTON STATE FOLLOW-UP

Background: As part of the ITEST proposal, the Washington State Education Research and Data Center (ERDC) agreed to match the 2006-2013 ROV competition program participants from Washington with the ERDC P-20 data and also to create a comparison group. They agreed to return high school, postsecondary, and workforce data. The economics section of the Washington State Office of Financial Management (OFM) Forecasting division agreed to do the statistical analysis of the ERDC data.

This analysis will explore two main research questions:

1) To what extent are the ROV competition participants the same/different from the general population of students, and

2) What is the impact of the ROV competition on the probability of attending college, studying STEM, persisting, and completing college degrees?

2015-2016 Progress: Between July and October 2015, MATE and the evaluator negotiated the work plan and budget with ERDC. We came to an agreement on work and budget, and ERDC indicated that they would integrate the final changes to the Statement of Work and produce a contract for signature. In February, 2016, we contacted ERDC about the contract, with no response.

In April, 2016, we contacted ERDC again, in preparation for the evaluator's presentation at the ITEST Summit. ERDC responded, provided assurances that they will do the work, and performed a quick match of the 2013 participants with the 2013-2014 school enrollment. Unfortunately, this was the wrong year of school enrollment. The 2013 participants should have been matched with the 2012-2013 school enrollment. As a result, the ERDC analyst was only able to match 139 of the 210 participants (match rate: 66%). The demographic information he found is below. **We share this data with the caution that the percentages will change when the participants are matched with the correct year's data.** Since the Pacific Northwest ROV competition draws students primarily from western Washington State, we also compiled the demographics for this region.

Table 2: Gender of 2012-2013 Pacific Northwest ROV Competition Participants, 2013-2014 All Washington State K-12 Students, and 2013-2014 All K-12 Students in Western WA

	2012-2013 MATE PNW (N=139)	2013-2014 All WA K12 Students (N=1,050,284)	2013-2014 All K12 Students in Western WA* (N=688,171)
Male	73%	52%	52%
Female	27%	48%	48%

Table 3: Programs for 2012-2013 Pacific Northwest ROV Competition Participants, 2013-2014 All Washington State K-12 Students, and 2013-2014 All K-12 Students in Western WA

	2012-2013 MATE PNW (N=139)	2013-2014 All WA K12 Students (N=1,050,284)	2013-2014 All K12 Students in Western WA* (N=688,171)
FRPL Eligible	37%	46%	41%
Special Ed Program	9%	52%	13%

Table 4: Race (Top Three of MATE PNW Participants) for 2012-2013 Pacific Northwest ROV Competition Participants, 2013-2014 All Washington State K-12 Students, and 2013-2014 All K-12 Students in Western WA

	2012-2013 MATE PNW (N=139)	2013-2014 All WA K12 Students (N=1,050,284)	2013-2014 All K12 Students in Western WA* (N=688,171)
White	75%	58%	57%
Hispanic/Latino	9%	21%	16%
Asian	9%	7%	10%

*Educational Service Districts 189, 114, 121, 113.[1]

As of June 2016, we do not yet have a signed contract with ERDC, though they assure us that they can and will do the work.

[1] Source: Office of the Superintendent of Public Instruction, Washington State Report Card, http://reportcard.ospi.k12.wa.us/Summary.aspx?groupLevel=ESD&schoolId=1&reportLevel=State&year=2013-14. Accessed July 20, 2016.

ROV COMPETITION STUDENT ALUMNI SURVEY

In June of 2015, we conducted the ROV Competition Student Alumni Survey. The goal of the alumni survey was to answer the questions: "Where are they now?" and, "To what extent did their involvement with MATE influence their trajectory?" The survey included questions about their higher education, employment, internships, scholarships and other opportunities that opened due to their involvement with the ROV competition. Results were included in the 2014-2015 evaluation report and were presented to the ROV competition regional coordinators at the 2015 Regional Coordinator Meeting.

NATIONAL STUDENT CLEARINGHOUSE DATA MATCH

Background: The National Student Clearinghouse (NSC) is a nationwide source of higher education information. Colleges and universities, numbering over 3,400 institutions enrolling over 96% of college students, share their enrollment data with NSC. The NSC database includes over 130 million students. See http://www.studentclearinghouse.org/ for further information about the NSC.

2015-2016 Progress: A total of 3,850 former competition participants were identified for matching with NSC data. These participants have birthdates that indicate that they are at least 18 years of age as of June 2016, and their addresses suggest that they live within the United States. MATE negotiated a contract with NSC in early June 2016 and was provided with access to the NSC's secure FTP to upload the file. After the file was uploaded, NSC provided a sample report, which showed that instead of providing analyzed aggregate data, the report will be a dataset of detailed, identified, individual student-level results. It turns out that the reports of analyzed aggregate data are only available to high schools.

The detailed reports are a mixed blessing, since, on the positive side, they will enable us to do more in-depth analysis. On the negative side, our original research plan that was approved by the Washington State University Institutional Review Board did not include access to identifiable individual student-level data. We submitted an IRB amendment to receive the identifiable data on June 20, 2016, and it was approved on July 14, 2016. NSC has informed us that they will run our match within one to two weeks and will release it to us once they receive payment.

This dataset will provide information on the participants' postsecondary activities. The NSC data will be useful for comparison with our other sources of follow-up data: the Washington State Follow-up and the alumni survey.

Curriculum and Online Instructional Resources

PRE-POST KNOWLEDGE TESTS

In the ITEST proposal, the MATE Center proposed creating a complete curriculum, tied to standards, with pre-post knowledge tests corresponding to each module. In 2014-2015, the MATE Center changed focus in response to user feedback in an intensive set of 103 interviews conducted as part of an NSF I-

Corps grant. Rather than a complete curriculum, PIs determined that teachers preferred online resources that they could incorporate into their own curricula. (See MATE Center Annual Report for further description of the training and professional development.)

With this information regarding teacher preferences, the MATE Center has changed focus from designing a complete curriculum to designing a well thought out menu of online curriculum modules and supporting resources, such as instructional videos, PowerPoint presentations, and other activities.

In addition, in 2015-2016, MATE began testing the course management system, Canvas by Infrastructure. Prior to this, the MATE curriculum materials were hosted on a combination of the MATE website and the Moodle course management system, which was slow and clunky. MATE PIs report that they are highly satisfied with Canvas, which is fast and easy to use.

MATE has started to transition their curriculum materials to Canvas. For instance, the 2016 Summer Institutes were hosted entirely on Canvas. The combination of the transition to Canvas and the popularity of using internet in the classroom (about 75% of the teachers at the Summer Institute use internet in their classrooms) provide the perfect setting for MATE to enable teachers to use the Summer Institute curriculum in their classrooms. As stated in the 2015-2016 MATE Annual Report:

> *Best of all, we can easily clone courses for other educators on the cloud and they do not need any special software or licenses, just 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 them modify it to suit their needs (which is critical to adoption and implementation) and collect pre and post-test data that are adapted from our assessments…. We will be working closely with Dr. Min Li in designing, piloting and assessing the psychometric quality for the NGSS-aligned pre-post knowledge tests.*

This plan will provide valuable data for the evaluation because it solves the logistical problem of asking teachers to provide their students' test data to MATE. With this approach, the teachers will administer the assessments, and the data will be available to MATE seamlessly.

One of the curriculum materials that is being transitioned to Canvas is the Diving into Sensors online course, which was piloted in 2015 with 63 faculty participants and is currently being run for the second time with 42 students. The course was rated positively by 85% of the participants (excellent 39%, good 46%, fair 11%, poor 5%, very poor 0%). The majority of participants indicated that their knowledge of the topics covered by the course was nonexistent, minimal, or low before the course, and after the course, the majority rated their knowledge as moderate, moderate to high, or high. The course covered the topics of microcontrollers, programming languages, Arduino, potentiometers, joysticks, voltage dividers, sensor technology, motor controllers, basic electronics, breadboards, soldering, and analogue to digital conversion.

ROV Competitions

Background: At the ROV competitions, input was solicited from as many stakeholders as possible, including students, teachers, parents, and judges/volunteers. The competition surveys were primarily administered as paper surveys in a "scannable" format; there was a web option as well. Data entry was completed by scanning the surveys and entering the written comments by hand. Data analysis was performed with the Statistical Package for the Social Sciences (SPSS). Student and parent surveys were offered in Spanish as well.

POST-COMPETITION SURVEYS: STUDENTS

At the ROV competitions, students were asked to complete surveys. The survey protocol was a modified version of the student survey that has been administered to more than 6,500 students over the past eight years at regional and international ROV competitions. The survey covered the following topics: awareness and interest in ocean STEM careers, increased desire to take STEM courses due to involvement in the program, awards/honors received as a result of competition experience, and self-assessment of change in STEM knowledge.

POST-COMPETITION SURVEYS: TEACHERS

Teachers also completed surveys at the ROV competitions. The survey protocol was a modified version of the faculty/mentor survey that has been administered to more than 1,350 respondents over the past eight years at ROV competitions. The survey addressed topics such as the value of the competition, incorporation of competition into course curriculum, interest in participating in future competitions, assessment of change in their students' STEM knowledge and skills, 21st Century skills, interest in STEM careers, and related topics.

POST-COMPETITION SURVEYS: PARENTS

In contrast to the student and teacher surveys, which have been conducted for years at MATE ROV competitions, the 2010 competition season was the first time parent input was solicited. Parents responded enthusiastically and seemed to appreciate the opportunity to provide input. Parent surveys addressed the topics of parental support of their children's interest in STEM and STEM careers, the value of the competition, and changes they have observed in their children since they became involved in the program. In 2015-2016, 440 parents and other family members (such as grandparents) completed the survey.

POST-COMPETITION SURVEYS: JUDGES

In the 2011 competition season, input was solicited for the first time from industry representatives serving as judges at the competitions. This survey collects information on the judges' experience at the competition, whether they feel it was a worthwhile use of their time, the skills of the students they observed, and their opinions on the usefulness of the competition in preparing future employees. In 2015-2016, 169 judges and 109 volunteers completed the survey.

PSYCHOMETRIC ANALYSIS: VALIDATION OF SCORING RUBRICS, IMPROVING INTERNAL CONSISTENCY OF POST-COMPETITION SURVEYS

2015-2016 Update: In 2015-2016, the MATE Center continued the valuable collaboration with Dr. Min Li, Associate Professor at the University of Washington's Department of Education. In this grant year, Dr. Li focused on validating the competition scoring rubrics, establishing inter-rater reliability of competition scoring, and improving the internal consistency of the post-competition surveys. In response to Dr. Li's analysis, the scoring rubrics were updated, as were the student and parent surveys. Please see below for Dr. Li's summary of work conducted in 2015-2016, findings, and plans for 2016-2017:[2]

***

The psychometric analysis to validate various instruments developed and used in this project focused on two main goals: (1) employing 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 (2) improving the internal consistency of existing surveys by adding questions and standardizing the question constructs.

Related to the goal of validating competition scoring rubrics, we analyzed the judge scores using both the Cronbach's alpha as the indicator of the internal consistency and the Generalizability (G) coefficients calculated based on the G theory. For the second goal of improving the internal consistency of the existing surveys, we performed the exploratory and confirmatory factor analysis with the survey items some of which had been refined and re-organized based on our previous analysis and identified the areas that survey items could be refined. The data for running the psychometric analysis came from collected from the round of 2015 competitions. The analytic procedures and syntax files can be easily applied with the collected from previous rounds to cross validate the validity issues that we have found from the last year's data collection.

In what follows we organize our report the psychometric findings into two sections corresponding to the two goals described.

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[2] Note that the table and figure numbers in Dr. Li's summary are separate from the numbering of the figures and tables elsewhere in the report.

Validation of Competition Scoring Rubrics

Participants' products to the ROV competition are scored by volunteering judges into four types of scores: (1) technical report that focuses on the technical aspects of the report that a team submits electronically; (2) mission that assesses the performance of the ROV demonstrated by the team; (3) poster that a team summarizes necessary information about their ROV project; and (4) presentation that the team interactively reports the ROV project to a group of audience, including judges and others.

Prior to the statistical analysis, we performed the content analysis of the scoring rubrics by reviewing the focus of each rubric and carefully comparing them against the competition manual. The manual is supposed to include all the instructions to the participants which need to explicitly communicate the scoring rubrics and expectations. Applying this guideline, we flagged parts that can be unclear or confusing for the students and then modified, simplified, and clarified these aspects of the competition manual to streamline the instructions and align them closely to each of the scoring rubrics. In addition, we made the language of the instructions consistent to the scoring rubrics and comparable across the four forms of products since several key words in the rubrics were changed from last round. We anticipated that this revision of articulating the scoring rubrics will ultimately improve the inter-rater reliability of the rubrics.

We chose to analyze the technical quality for only two of the four rubrics: Sales Presentations and Technical Documentation. The mission rubric was believed to yield a much higher reliability because it directly evaluates whether the vehicle performed the tasks or it did not, which less likely involves subjective judgments compared to other three rubrics. The Display rubric (previously called as poster rubric) in our prior analysis was found to yield a reliable scoring process as using two raters led to absolute Generalizability coefficients larger than .89 for any pair of judges. Therefore, we only evaluate the amount of measurement error for the remaining two rubrics.

For these two rubrics, experienced engineers were assigned into triads each of which then was randomly assigned to rate a group of eight to ten projects.

We employed both the classical test theory (CTT) and Generalizability theory to examine the inter-rater reliabilities. For the CTT, we computed the Cronbach's alphas. For the G theory, we used the random model of a project x judge (P x J) design. This should result in three variance components: variance due to product differences as the object of the measurement (σ_p^2) as well as two sources of measurement errors, variance due to the judge effect (σ_j^2), and variance due to the product by judge interaction confounded with residual ($\sigma_{pj,e}^2$). We also calculated two types of G coefficients. Absolute G coefficients indicate the extent to which the judges provided comparable scores or not when evaluating projects; in contrast, relative G coefficients refer to the extent to which the judges ranked the projects consistently or not regardless if some might give much higher scores compared to their peer judges. In the one-facet *model of P x J design, relative G coefficients are exactly the same as the Cronbach's alpha coefficients under the CTT approach. Relative G coefficients are more relevant for this project because score reliability only matters regarding how the judges ranked the projects submitted by the competition teams. As we aim to align the specifics of each rubric to the NGSS, it will be important to take the absolute G coefficients into account. Absolute G coefficients allow us to examine the reliability of score inferences when we evaluate how well projects demonstrate participants' mastery of the targeted NGSS standards.*

Table 1 summarizes the variance components and G coefficients for the two rubrics we studied. Our interpretations of results primarily focus on the relative G coefficients. Sales presentation rubric was relatively more reliable compared to the technical report rubric we studied. For the sales presentation rubric (previously called as engineering rubric), the relative G coefficients were mostly greater than .80 even when randomly selecting any one judge instead of using two judges based on the scores at least from six of the eight triads of judges, indicating that fewer than 80% of score variation was accounted for by the measurement error associated with the judge facet. In other words, only one rater is needed due to the small amount of measurement error. Similarly, the technical report rubric was reliably applied by the judges as well. All the relative G coefficients were satisfactory with magnitudes greater than or closer to .80 when using at least 2 judges. For this rubric, using only one judge may introduce a sizeable amount of measurement error for scores assigned.

Importantly, for both rubrics, the reliability coefficients varied greatly across the triads of judges. For Teams 6-9, each triad of judges scored consistently the projects to such a degree that only one of the judges would be needed while still maintaining an interrater reliability above .92. However, Team 12 was the least reliable as the three judges rarely reached any agreement at all with each other when ranking the projects based on this rubric. In addition, measurement error associated with the judge facet was also noticeable for the four other teams with respect to the sales presentation rubric.

Table 1. Estimated Variance Components and G Coefficients for the Technical Report and Sales Presentation Rubrics

ID of Judge Team[a]	Estimated Variance Components In P x J (Project x Judge) Design			G Coefficients					
				Using 1 Judge (n_j=1)		Using 2 Judges (n_j=2)		Using 3 Judges (n_j=3)	
	EVC (project)	EVC (judge)	EVC (pj,e)	Abs. G Coeff.[b]	Rel. G Coeff.[c]	Abs. G Coeff.	Rel. G Coeff.	Abs. G Coeff.	Rel. G Coeff.
Sales presentation scores (previously called as engineering scores)									
1	52.10	13.33	35.63	0.516	0.594	0.680	0.745	0.762	0.814
2	24.00	24.27	35.30	0.287	0.405	0.446	0.576	0.547	0.671
3	153.93	6.09	43.83	0.755	0.778	0.860	0.875	0.902	0.913
4	102.58	0.00	16.01	0.865	0.865	0.928	0.928	0.951	0.951
5	65.62	14.89	7.78	0.743	0.894	0.853	0.944	0.897	0.962
6	138.02	3.42	7.38	0.927	0.949	0.962	0.974	0.975	0.982
7	276.68	0.41	11.88	0.957	0.959	0.978	0.979	0.985	0.986
8	358.98	0.00	22.76	0.940	0.940	0.969	0.969	0.979	0.979
Pooled[d]	1171.91	62.40	180.57	0.828	0.866	0.906	0.928	0.935	0.951

Technical report scores									
9	*765.91*	*22.26*	*45.38*	*0.919*	*0.944*	*0.958*	*0.971*	*0.971*	*0.981*
10	*45.52*	*76.69*	*49.88*	*0.264*	*0.477*	*0.418*	*0.646*	*0.519*	*0.732*
11	*179.17*	*42.27*	*66.40*	*0.622*	*0.730*	*0.767*	*0.844*	*0.832*	*0.890*
12	*30.31*	*96.58*	*82.09*	*0.145*	*0.270*	*0.253*	*0.425*	*0.337*	*0.526*
13	*127.35*	*28.65*	*43.94*	*0.637*	*0.743*	*0.778*	*0.853*	*0.840*	*0.897*
14	*156.83*	*35.82*	*86.47*	*0.562*	*0.645*	*0.719*	*0.784*	*0.794*	*0.845*
15	*130.71*	*51.97*	*41.41*	*0.583*	*0.759*	*0.737*	*0.863*	*0.808*	*0.904*
16	*127.35*	*98.88*	*85.38*	*0.409*	*0.599*	*0.580*	*0.749*	*0.675*	*0.817*
Pooled	*1563.15*	*453.11*	*500.96*	*0.621*	*0.757*	*0.766*	*0.862*	*0.831*	*0.903*

Notes: a. Both technical reports and sales representation were scored by three judges independently.

b. Abs. G coeff. refers to absolute G coefficient.

c. Rel. G Coeff. refers to relative G coefficient. Relative G coefficient when ***using 3 judges*** *was equivalent to the Cronbach's alpha obtained.*

d. Pooled estimates were based on the sum of the estimated variance components. The estimates indicate the averaged reliabilities across multiple judge triads.

In order to further understand the reasons why the technical report rubric was much more demanding to maintain a reasonable interrater reliability, we took a closer look at the reliabilities of sub-categories (also called as sub-scales that judges needed to assign scores to). We chose to examine the four sub-categories which were considered as the most relevant in comparison to other ones. Table 2 reports the estimated variance components from the G studies and the G coefficients for running the decision studies when using different number of judges. We summarize the patterns of relative G coefficients in Table 3.

As shown in Tables 2 and 3, the reliabilities were found uneven across the sub-categories and across the judge triads. Generally the G coefficients for sub-scales yielded much lower reliabilities compared to the total score because the latter should have more score variations as the sum of all the sub-categories. It appeared that only one sub-category was attainable for most judge triads to score consistently: Safety because at least half of the eight triads of judges were able to maintain a relative G coefficient of .75 (see Table 3). In contrast, the remaining three sub-categories were relatively challenging for the judges (highlighted in grey in Table 3) because at least more than half of the triads were able to maintain their reliability coefficient at .60. None of the sub-rubric was found too extremely problematic for judges to make reliable scoring decisions compared to their peer judges.

The reliabilities mostly varied across the scoring teams. The judges within Triads 10, 14, and 15 tended to have a stable interrater reliability virtually for all the sub-categories of the technical report rubric. The judges in Triads 9 and 11 had the lowest interrater reliability across multiple sub-categories. This finding suggests that whereas the former two triads' scoring performance could be potentially improved by providing additional training support for some sub-categories, they may need more substantial training that tap into deep issues to check if they disagree with any fundamental principles that they tend to apply during their scoring processes.

Table 2. Estimated Variance Components and G Coefficients for Important Sub-category Codes of the Technical Report Rubric

	Estimated Variance Components In P x J (Project x Judge) Design			G Coefficients					
				Using 1 Judge (n_j=1)		Using 2 Judges (n_j=2)		Using 3 Judges (n_j=3)	
Triad ID of Judges	EVC (project)	EVC (judge)	EVC (pj,e)	Abs. G Coeff.	Rel. G Coeff.	Abs. G Coeff.	Rel. G Coeff.	Abs. G Coeff.	Rel. G Coeff. [a]
Vehicle Systems									
9	1.04	0.20	2.17	0.304	0.323	0.466	0.488	0.567	0.589
10	0.64	2.43	0.63	0.173	0.503	0.295	0.670	0.386	0.752
11	0.10	3.48	1.52	0.020	0.062	0.038	0.116	0.057	0.165
12	0.83	0.97	1.94	0.221	0.299	0.362	0.460	0.460	0.561
13	0.07	0.13	1.99	0.030	0.032	0.058	0.062	0.085	0.090
14	4.70	0.37	2.14	0.652	0.687	0.789	0.815	0.849	0.868
15	0.73	1.02	1.27	0.240	0.363	0.388	0.533	0.487	0.631
16	2.28	0.36	1.26	0.585	0.643	0.738	0.783	0.808	0.844
Pooled	10.371	8.966	12.933	0.321	0.445	0.486	0.616	0.587	0.706
Teamwork									
9	0.74	0.23	0.81	0.415	0.477	0.586	0.646	0.680	0.732
10	0.49	1.39	0.76	0.186	0.393	0.314	0.565	0.407	0.660
11	0.61	0.49	1.23	0.262	0.331	0.415	0.498	0.516	0.598
12	0.46	0.10	0.67	0.377	0.408	0.547	0.580	0.644	0.674
13	0.79	0.13	0.50	0.557	0.611	0.715	0.759	0.790	0.825
14	1.61	0.21	0.83	0.606	0.659	0.755	0.795	0.822	0.853
15	0.16	0.14	1.08	0.117	0.131	0.210	0.231	0.285	0.311
16	0.42	0.33	0.72	0.286	0.368	0.445	0.538	0.546	0.636
Pooled	5.281	3.016	6.602	0.354	0.444	0.523	0.615	0.622	0.706
Overall Presentation									
9	0.93	3.74	4.34	0.104	0.177	0.000	0.000	0.000	0.000
10	0.57	1.97	4.23	0.084	0.118	0.576	0.603	0.670	0.695
11	0.00	2.94	1.39	0.000	0.000	0.548	0.548	0.646	0.646
12	2.39	0.37	3.15	0.404	0.431	0.945	0.945	0.963	0.963
13	1.84	0.00	3.03	0.378	0.378	0.678	0.736	0.760	0.807
14	17.10	0.00	1.99	0.896	0.896	0.433	0.565	0.533	0.661
15	4.80	1.11	3.44	0.513	0.582	0.678	0.736	0.760	0.807
16	1.71	1.85	2.63	0.276	0.394	0.618	0.708	0.709	0.784
						0.000	0.000	0.000	0.000
Pooled	29.335	11.988	24.202	0.448	0.548	0.576	0.603	0.670	0.695
Safety									
9	0.32	0.00	1.70	0.157	0.157	0.271	0.271	0.358	0.358
10	2.07	0.00	0.63	0.765	0.765	0.867	0.867	0.907	0.907
11	2.62	0.51	0.99	0.636	0.726	0.778	0.841	0.840	0.888
12	2.28	0.13	0.82	0.705	0.736	0.827	0.848	0.878	0.893
13	2.01	0.05	0.74	0.717	0.731	0.835	0.845	0.884	0.891

14	5.82	0.01	0.37	0.939	0.940	0.968	0.969	0.979	0.979
15	0.81	0.19	1.04	0.397	0.437	0.569	0.608	0.664	0.700
16	0.54	0.32	1.25	0.256	0.301	0.407	0.463	0.507	0.564
Pooled	16.451	1.210	7.538	0.653	0.686	0.790	0.814	0.849	0.867

Note: a. Relative G coefficients, when three raters are randomly selected to form a scoring team below .600, were in orange color.

Table 3. Summary of Relative G Coefficients for Sub-categories of the Technical Report Rubric

Triad ID of Judges	Vehicle Systems	Overall Presentation	Teamwork	Safety	Summary of Number of Rel. G Coeff. (ρ^2) across 9 Sub-categories: Number of $\rho^2 \geq .60$	Number of $\rho^2 \geq .75$
9	0.589	0.732	0.393	0.358	1	1
10	0.752	0.660	0.287	0.907	3	2
11	0.165	0.598	0.000	0.888	1	1
12	0.561	0.674	0.695	0.893	3	1
13	0.090	0.825	0.646	0.891	2	2
14	0.868	0.853	0.963	0.979	4	4
15	0.631	0.311	0.807	0.700	3	1
16	0.844	0.636	0.661	0.564	3	1
Max score pts	9	15	6	6		
Relevance	High	High	High	High		
Summary of Number of Rel. G Coeff. (ρ^2) Across Eight Triads						
Number of $\rho^2 \geq .60$	4	7	5	6		
Number of $\rho^2 \geq .75$	3	2	2	5		

Overall, the reliability analysis based on the CTT and G studies provide supportive evidence for the psychometric quality of two rubrics: technical report and sales presentation. For the sales presentation rubric, our analysis indicates that only one judge is needed to maintain an interrater reliability at an acceptable level for the relative score interpretation (i.e., rank ordering the competition projects). For the technical report rubric, it is worth noting that at least two judges were required to ensure the reliability of the scoring work.

A detailed analysis with the sub-categories for the technical report rubric revealed that the scoring inconsistency mostly was caused by a few challenging rubrics and a couple of teams of judges who tended to score very differently. The G studies with the sub-categories of the sales presentation rubric *offered three insights for improving the interrater reliability in next project year and any possible future use:*

(1) Triads 9 and 11 definitely need additional training to get familiar with the rubrics and close monitoring of their scores in the upcoming competition events. A follow-up analysis confirmed that the inconsistency was caused by all of the three judges rather than the situation that two judges scored reliably but differed from the other judge. The judges may need different types of training activities to discuss the rubrics or the underlying principles and assumptions that they have chosen to apply.

(2) This relatively newer version of the technical report rubric has been revised based on the findings from last year, by using well-articulated language, breaking down and elaborating multiple facets for complex sub-categories if needed, and aligning the detailed descriptions for each performance level (see Figure 1 for an example of the rubric layout). Overall many of the sub-categories were found with acceptable interrater reliability after the clarity and easiness of the rubric was improved during last year. Three sub-categories (i.e., Overall Presentation, Vehicle Systems, and Teamwork) are the only two candidates which might need some tinkering because a couple of the eight triads of judges failed to apply this rubric consistently, with their interrater reliability coefficients as .50 or lower.

2015 MATE ROV Competition Sales Presentation Evaluation Rubric

Class (circle one): RANGER EXPLORER Judge:______________________________

Team Presentation					
Category	**Scoring Criteria**				**Points**
Teamwork	**3 - Excellent**	**2 - Very Good**	**1 - Good**	**0 – Poor or missing**	
Preparation of presentation and required documentation	Strong whole team effort, exceptionally prepared, documentation very strong	Clearly prepared, organized, articulate, each team member contributed, documentation in order	Prepared, fairly organized, partial team effort, good documentation	Underprepared, not well organized, lack of whole team effort, poor or missing documentation	
Originality/Salesmanship					
Style of presentation, effective salesmanship	Dynamic presentation, team went above and beyond expectations, tied presentation well into theme/mission	Good presentation, satisfied expectations, make links to theme	Lackluster presentation, below expectations, vague mention of theme	Poor presentation, lacked any salesmanship or connection to theme	
Insight/Creativity					
Innovations, challenges faced, determination to resolve challenges	Innovative/creative solutions presented to well described challenges, tenacity quite evident	Interesting solutions, not necessarily novel, described challenges faced, demonstrated tenacity	Solutions demonstrated for challenges faced, but not particularly creative, did not demonstrate tenacity	Did not face challenges well, did not understand challenges or solutions well enough to describe	
Understanding					
Demonstration of ROV systems, science, operation and mission theme	Strong understanding of ROV systems, provided much detail of underlying science, and application to theme	Good understanding of ROV systems, provided some detail of underlying science, and application to theme	Some understanding of ROV systems, underlying science, and application to theme	Little understanding of ROV systems, underlying science, and application to theme	
Resources/Budget					
How was budget developed and adhered to during competition phases, cost analysis, overall cost of vehicle	Thorough description of budget planning and following, acknowledgement of donations, fundraising strategies, excellent use of funds	A description of budget planning with good use of funds but missing one of the following components: - acknowledgement of donations, - fundraising strategies, - justified re-use of components	Loose description of budget planning with mediocre use of funds and missing 2 or more of the following components: - acknowledgement of donations, - fundraising strategies, - non-justified re-use of components	Poor description, poor use of funds, no acknowledgement of donations	
Corporate team memory					
	Described how the team and vehicle evolution and mission contributed to the design decisions or if new team, excellent description of research conducted to begin decision process	Described influences from past team members or vehicle design or if new team, good description of research conducted to begin decision process	Little corporate team memory demonstrated, or if new team, little description of research conducted to begin decision process, basically just got lucky	It was clear that the team or only one team member understood the vehicle	

Figure 1. One page of the scoring rubric for the Sales Presentation

(3) *Revisions for these three problematic sub-categories should be waited after we conduct additional analysis related to construct validity. The planned factorial analysis will help us pinpoint how the sub-categories relate to the underlying construct intended to measure. We also plan to conduct a cognitive interview with a small sample of judges to unpack their reasoning processes when they review projects and assign scores as well as possible difficulties or confusions they may experience when applying the rubrics. With new findings we may recommend to collapse or drop a couple of sub-categories to simplify the cognitive process of making scoring decisions.*

Improving the Internal Consistency of Existing Surveys

Building on last year's analysis of the internal structure and consistency of four existing surveys based on the data collected from all the competition events in 2014, we were able to refine the survey questions of Student Survey and Parent Survey because both Instructor Survey and Volunteer Survey were found with satisfactory measurement properties. The revision comments for Student Survey and Parent Survey had focused on four issues: (1) change items that did not behave well in the Cronbach's alpha by clarifying the wording of the stem or the labels of the Likert scale or even drop items when they overlapped significantly with others; (2) use similar layouts to present survey questions and the Likert scale across the four surveys; (3) make the use of words and phrases consistent across all the four surveys so that potentially the response patterns can be compared; and (4) revisit and revise items that were grouped around one common stem as multiple statements when appropriate or create new set to organize items into such a set.

For the survey data collected last year, we again evaluated the technical quality of each of the surveys. We first examined the descriptive statistics to make sure that responses were properly recoded if needed and checked if items may involve a usually high non-response rate (which was one indication that the wording of the survey question might be confusing or ambiguous to respondent) or may have too small standard deviation that can potentially cause poorly behaving items due to the restricted range of scores. We then performed both exploratory factor analysis (EFA) and confirmation factor analysis (CFA) to verify the internal structure of the construct. Lastly, we calculated the Cronbach's alpha coefficients as indicators for internal consistency for the sub-scales corresponding to the factor model identified by the factor analyses. In what follows we only report the key findings of the psychometric analysis based on the CFA and Cronbach's alpha.

Student Survey. Based on the χ^2 value, we recommend the 3-factor model because it has a much lower χ^2/df ratio and statistically better than the other two factor models (see Table 4 for fitness statistics and Figure 1 for factor loadings for each tested model). Still this 3-factor model is not statistically robust which means there is room to improve the model fit and factor loadings of the survey items.

Table 4. Study Survey Items: Good-of-fit Indices for 1-, 3- and 4-factor Models (n = 1423)

Model	*Chi-square*	*df*	*CFI*	*TLI*	*RMSEA*
1-factor	*7702.44***	*189*	*0.94*	*0.93*	*0.17*
3-factor	*2494.99***	*186*	*0.98*	*0.98*	*0.09*
4-factor	*2545.04***	*183*	*0.98*	*0.98*	*0.10*

*** p < .01*

As shown in Table 4, the factor loadings and R-squared statistics of the survey questions provide supportive evidence that the three factors are distinct constructs, differing from each other. The number of items belongs to Factors 1, 2, and 3 is 8, 6, and 7, respectively. Factor 1 items mainly measure student's interest in the STEM field; Factor 2 items mainly assess student's skills and knowledge in the STEM field; and Factor 3 items mainly focus on measuring how student can communicate well in the STEM field. Table 5 reports the factor loading based on the three-factor CFA model.

Table 5. Student Survey Items: Statistics of Observed Variables based on the Three-factor CFA Model (n = 1423)

	Factor Loading			
Rubrics	*1*	*2*	*3*	*R-squared*
Q03A	*0.75***			*0.56*
Q03B	*0.81***			*0.65*
Q03C	*0.8***			*0.63*
Q03D		*0.74***		*0.45*
Q03E			*0.72***	*0.38*
Q04A	*0.81***			*0.55*
Q04B	*0.77***			*0.51*
Q04C	*0.71***			*0.66*
Q04D	*0.67***			*0.60*
Q04E	*0.69***			*0.50*
Q05A		*0.85***		*0.47*
Q05B		*0.81***		*0.73*
Q05C		*0.74***		*0.66*
Q05D		*0.85***		*0.55*
Q05E		*0.61***		*0.72*
Q06A			*0.81***	*0.66*
Q06B			*0.78***	*0.61*

Q06C	*0.88***	*0.77*
Q06D	*0.88***	*0.77*
Q06E	*0.71***	*0.50*
Q06F	*0.76***	*0.57*

Table 6 below provides the detailed information for the underlying factors as we chose the 3-factor model. We report the internal consistency for the three factors (i.e., sub-scales) informed by the CFA. All of the three sub-scales yield satisfactory internal consistency as items tended to sufficiently capture the intended construct with less amount of variabilities due to the item variations compared to the previous versions of Student Survey.

Table 6. Descriptions of Sub-scales for Student Survey and Internal Consistency Statistics

Factor	Questionnaire Item IDs	Description of the Factor	Cronbach's Alpha Coefficient
1	Q03A, Q03B, Q03C, Q04A,Q04B, Q04C, Q04D, Q04E	More interested in STEM field because of the ROV project	0.88
2	Q03D, Q05A, Q05B, Q05C, Q05D, Q05E	Increased skills and knowledge in STEM field because of the ROV project	0.83
3	Q03E, Q06A, Q06B, Q06C, Q06D, Q06E, Q06F	Better communicate in STEM field because of the ROV project	0.88

<u>Parent, Instructor, and Volunteer Surveys</u>. Following the same procedure described above, we examined the internal structure of the three other surveys based on the content review of all the survey items, using both EFA and CFA modeling. It is important to reiterate that only Parent Survey had gone through the revision process based on last year's findings whereas the other two surveys appeared to demonstrate acceptable psychometric quality.

Table 7 reports the CFA model fits in the form of χ^2 statistics and recommends one model for each survey that yields the best model fit and theoretically aligns with our assumptions of the underlying constructs.

Table 7. CFA Model Fit for Parent, Instructor, and Volunteer Survey Items

CFA Model	Chi-square	df	CFI	TLI	RMSEA	Selected Model
Parent Survey	(n = 346)					
1-factor	1952.92**	77	0.92	0.91	0.27	
3-factor	164.74**	74	1.00	1.00	0.06	x
Instructor Survey	(n = 306)					
1-factor	321.80**	44	0.96	0.95	0.14	
2-factor	160.50**	43	0.98	0.98	0.09	x
Volunteer Survey	(n = 209)					
1-factor	794.30**	65	0.90	0.88	0.23	
3-factor	127.59**	62	0.99	0.99	0.07	x

For each survey, we continued to calculate the internal consistency of survey items for sub-scales for the recommended model based on the factor analysis results (see Table 8). All of the sub-scales used in these surveys were found with satisfactory internal consistency, even just with three to six items per sub-scale. Some of the results also confirmed the previous findings for Instructor and Volunteer Survey continued to yield high cronbach's alpha coefficients for their sub-scales.

Table 8. Descriptions of Sub-scales for Parent, Instructor, and Volunteer Surveys and Internal Consistency Statistics

Factor	Survey Item IDs	Description of the Factor	Cronbach's Alpha Coefficient
Parent Survey			
1	Q4A,Q4B, Q4C, Q4D	Grades improved because of the ROV project	.88
2	Q5A, Q5B, Q5C, Q5D	Children love the STEM field more because of the ROV project	.85
3	Q6A,Q6B,Q6C, Q6D, Q6E, Q6F	Children positively affected because of the ROV project	.90
Instructor Survey			
1	Q4A,Q4B, Q4C, Q4D, Q4E, Q4F	Comments on the effects of the ROV competition on student learning	. 85
2	Q5A, Q5B, Q5C, Q5D, Q5E	The ROV project is valuable to me	.77

Volunteer Survey			
1	Q3A, Q3B, Q4A,Q4B, Q4C	Overall comments on the ROV competition experiences	.87
2	Q5A, Q5B, Q5C	Positive comments on ROV program	.84
3	Q6A, Q6B, Q6C, Q6D, Q6E	Skills improved through ROV program	.86

Plan of Psychometric Analysis in Year 4

In Year 4, we will continue with the psychometric work by replicating the current data analysis procedures and incorporate new empirical evidence to evaluate the validity claims and plan for a measurement publication for the scoring rubrics used for the ROV competition.

Validation of Competition Scoring Rubrics. We will continue the interrater reliability analysis using CTT and G theory with the judge scores collected from Year 3. Also based on the findings, we will revisit and refine the scoring rubric for the Sales Presentation rubric, especially few sub-categories, and develop annotated examples and scoring tips for these challenging sub-categories.

Furthermore, we plan to conduct three validity studies with the rubric scores of poster, engineering, and technical report and spend our energy for the last study:

(1) *A set of factor analysis modeling with the sub-category scores. After we establish the interrater reliability, we will run the structural equation modeling (SEM) to perform the factor analysis to identify the internal structure for each rubric. This will allow us to determine whether some sub-categories can be collapsed (or dropped if the sub-category is difficult to maintain interrater reliability and does not contribute to the underlying constructs).*
(2) *Multi-trait multi-method (MTMM) correlation to explore the convergent and discriminant evidence of measuring various sub-scales of students' engineering performance. We hypothesize that the correlation patterns across the three rubrics (e.g., are the Design Rationale scores from both poster and technical report highly correlated?) can be empirically tested, which then can inform us to revise the three rubrics to ascertain what aspects of student performance can be captured by all the three rubrics or uniquely assessed only by one particular rubric.*
(3) *Cognitive interview with the judges via audio-taped conference calls. We will recruit the judges for the Scales Presentation and Technical Report rubrics to talk aloud their scoring decisions related two projects selected from a previous competition and provide comments about the rubric pages. We will ask each judge to explicitly explain why one judge gave a certain category, etc. The transcriptions will be analyzed to understand how judges made evaluative decisions when applying the rubrics, what evidence they chose to focus on, and which parts or pieces of rubrics caused inconsistency or difficulties in scoring. In addition to the research purpose, the transcribed excerpts of the cognitive interview can be augmented with annotations as training examples for new or returning judges.*

<u>Analysis of Existing Survey</u>. We will replicate the factor analysis and internal consistency analysis with the data collected in Year 3 to cross validate the findings for the four surveys and closely monitor whether the technical quality of revised items in Student Survey and Parent Survey continue to perform well. More importantly, we will start to streamline four surveys to ensure that information can be triangulated across multiple surveys by running regression analysis and SEM with latent variables in order to compare the response patterns. Examples of the research questions include: did students who participated in the ROV competition for multiple times report higher scores in academic outcomes than their peers who only participated once? Did students or instructors report the same obstacles for the ROV competition?

<u>Analysis of Knowledge Tests</u>. If time allows, we would like to evaluate the psychometric properties of the knowledge tests. We envision that we can start with two important studies to address the reliability and validity issues:

(1) Item analysis with both the pretest and posttest items to produce item parameters of difficulty index and discrimination index as well as the Cronbach's alpha. This will enable us to flag items that may have technical problems, e.g., too difficult to differentiate high performing examinees from those with little understanding.

(2) Potentially if the sample size allows, we can also execute the factor analysis to examine the dimensionality of the measured construct, the differential item functioning analysis to determine whether items may bias against particular sub-groups (e.g., gender, or socio-economic status), and the index of instructional sensitivity to evaluate whether items reflect the amount of opportunities to learn involved in the PD activities.

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Regional Workshops

PRE AND POST TEACHER WORKSHOP SURVEYS

Pre and post paper surveys were administered to teacher workshop attendees at the beginning of the workshop day and at the end of the training. The surveys addressed issues of teacher confidence facilitating STEM learning experiences, commitment to bringing a team to competition, concerns about mentoring students in designing and building an ROV, expectations of the workshops, and additional ways that the regional coordinators and the MATE Center could support the participants.

Summer Institute

IMMEDIATE FEEDBACK AND SIX-MONTH FOLLOW-UP SURVEYS

The evaluation of the Summer Institutes is a two-step process, collecting feedback from the participants immediately after the Institutes (using the Institute feedback surveys) then again a year later (using the

Institute follow-up surveys). The follow-up surveys intend to measure the Institutes' longer-term impact and, in particular, to compare participants' actions once they returned to their classrooms with the intentions they had expressed at the close of the Institute. Because of the timing of the Summer Institute and the evaluation reporting, this evaluation covers the 2015 Summer Institute.

Other Data Sources

Additional data sources informing the evaluation include the annual reports turned in by the regional coordinators to the ITEST grant PI, observations of the Pacific Northwest regional competition, review of regional fidelity reports (based on site visits by the PIs and evaluator), review of participation data, unsolicited letters sent from students, parents and teachers, website review and document review, including supporting technical materials and the MATE Center's annual report.

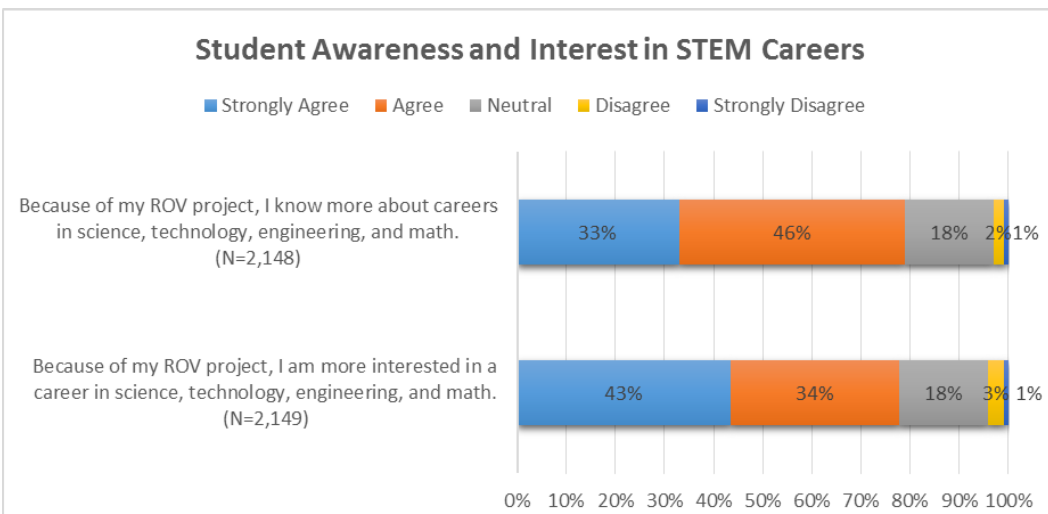
FINDINGS

Project Goal 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

Evaluation Question(s) 1.1. To what extent did the MATE robotics activities lead to an increase in the students' interest in and knowledge of STEM content and STEM careers? Did educators and parents observe an increase in the students' interest in STEM content and STEM careers as a result of the robotics activities? An increase in the students' STEM knowledge and skills and 21st Century workplace skills?

Increased Awareness of and Interest in STEM Careers: In the post-competition surveys, over three-quarters of the students (79%, N=2,148) indicated that due to their ROV project, they knew more about careers in science, technology, engineering, and math (STEM), and over three-quarters (77%, N=2,149) stated that their ROV project made them more interested in pursuing a STEM career.

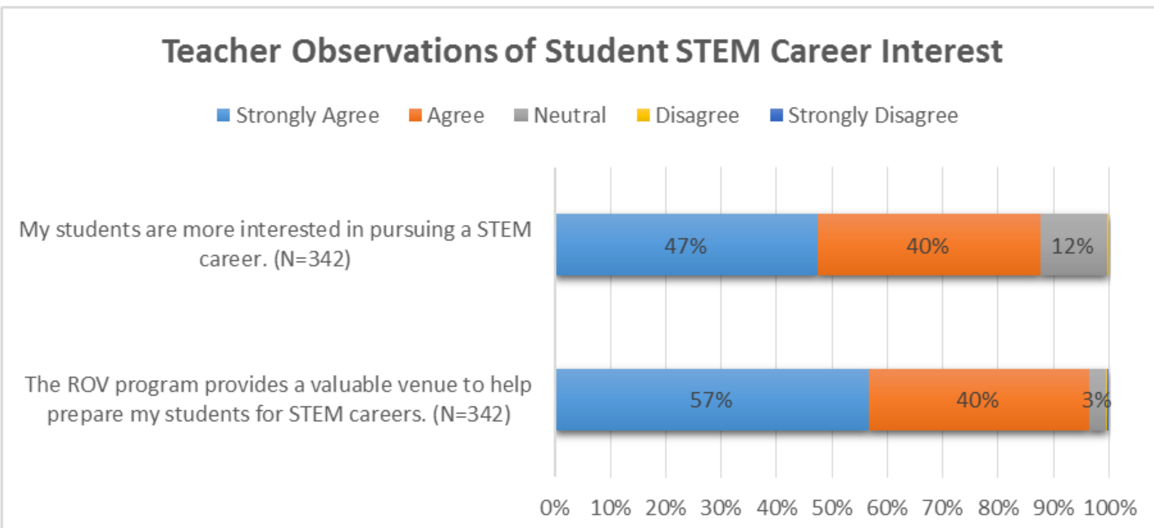
Figure 1: Effect of ROV Project on Students' Awareness and Interest in STEM Careers



Overall, 80% of the students (N=2,125) were interested in a STEM career; 16% were not sure, and 4% were not interested in a career in this field. Students mentioned wanting careers such as computer engineer, marine scientist, mechanical engineer, aeronautical science, environmental scientist, and astronaut (of interest since NASA hosted the international competition at the Neutral Buoyancy Lab). Students noted that their experience in the ROV program sparked their interest in STEM careers, with comments such as the following: "Participating in this program has made me interested on working with underwater vehicles as a career."

Among the teachers/mentors who completed post-competition surveys, 87% (N=342) indicated that they had observed that their students were more interested in pursuing a STEM career since they began designing and building their ROVs. Ninety-seven percent (97%, N=342) agreed that the ROV program provided a valuable venue to help prepare their students for STEM careers.

Figure 2: Teacher Observations of Student STEM Career Interest



Parents also noted an increased awareness and interest in STEM careers; 92% (N=424) agreed or strongly agreed that due to the ROV project, their child(ren) know more about STEM careers (61% strongly agreed, 31% agreed, 7% neutral, 0% disagreed, 0% strongly disagreed, 0.9% don't know). Also, 88% (N=423) agreed that participating in the ROV project has led their children to be more interested in pursuing a STEM career (61% strongly agreed, 28% agreed, 11% neutral, 0% disagreed, 0% strongly disagreed, 0.7% don't know). Parents described their children's interest in STEM careers in comments such as the following:

> *It helped solidify his career choice (mechanical engineering). Excellent program!*

> *He just absolutely loved it and is strongly considering a career in Marine Engineering.*

Increased Interest in STEM: Over three-quarters of the students (85%, N=2,137) stated that their ROV project made them want to learn more about science, technology, engineering, and math (50% strongly agreed, 35% agreed, 12% neutral, 2% disagreed, 1% strongly disagreed). As one student explained his experience, "I never enjoyed anything in STEM until I started underwater engineering in high school and went to MATE regionals."

Students indicated that their ROV projects increased their desire to take courses in engineering (77%, N=2,146), science (74%, N=2,138), computer science (71%, N=2,132), math (61%, N=2,128), and other hands-on classes or club activities like robotics, electronics and shop courses (87%, N=2,35). (See *Figure 3* below.) One student saw the connection between the

ROV Program Testimonials

Students

It made me a better leader and a more mature person.

Participating in ROV has only further increased my passion for engineering.

Parents

Her confidence level has sky-rocketed. She feels like she can speak up more; she has less fear of participation. This has been an all-around excellent experience for her.

My wonderfully nerdy son has found a place to bloom. He loves to talk with other teams about their ROVs. I love to watch him get inspired for his future in science.

My son has a learning difference, yet despite this, he actively participated, supported his team, and was supported by them. Our team of no college graduate parents envision themselves as future engineers.

Faculty/Mentors

MATE competitions provide exciting and challenging mission scenarios that do an excellent job of engaging my students.

This is a wonderful program that teaches students many skills applicable to real life. Students are motivated, enthusiastic, and learn without even realizing it.

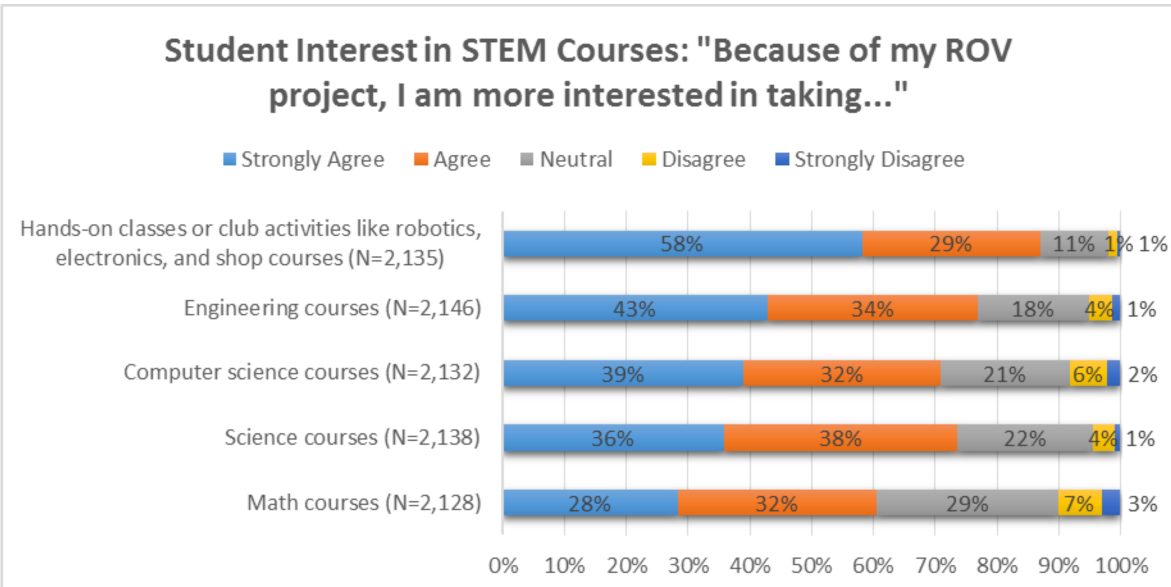
This program totally engages the students.

competition and his or her courses in the following quotes:

The MATE competition was an amazing experience to have. It has helped me in a lot of school subjects and skills.

In the post-competition survey, 94% of the teachers/mentors (N=343) indicated that their students were more interested in learning about science, technology, engineering and math (54% strongly agreed, 40% agreed, 6% neutral, 0.3% disagreed, 0% strongly disagreed).

Figure 3: Effect of ROV Project on Students' Interest in STEM Courses



Parents concurred with the other sources reporting increased student interest in STEM. Ninety-six percent (96%) of the parents surveyed (N=431) stated that building an ROV has made their child more interested in learning about science, technology, engineering or math (66% strongly agreed, 30% agreed, 4% neutral, 0% disagreed, 0% strongly disagreed, 0.2% don't know). Parents wrote comments such as the following:

She is more interested in problem solving and engineering, and what is happening in the science world today.

[My child is] excited about studying robotics/mechatronics in college.

This is my second child in the ROV program. My first child is currently a junior in college in electrical engineering due to the influence of the ROV program. My second child is also interested and working towards subjects for engineering.

He is completely convinced to study mechanical engineering and more...

Increased STEM Knowledge and Skills: In the post-competition surveys, students reported increased skills and knowledge due to their ROV project in several subjects: engineering (92%, N=2,127), technology (91%, N=2,123), science (81%, N=2,131), the competition theme (73%, N=2,112), and math (63%, N=2,118). Students noted their increased STEM skills in comments such as the following:

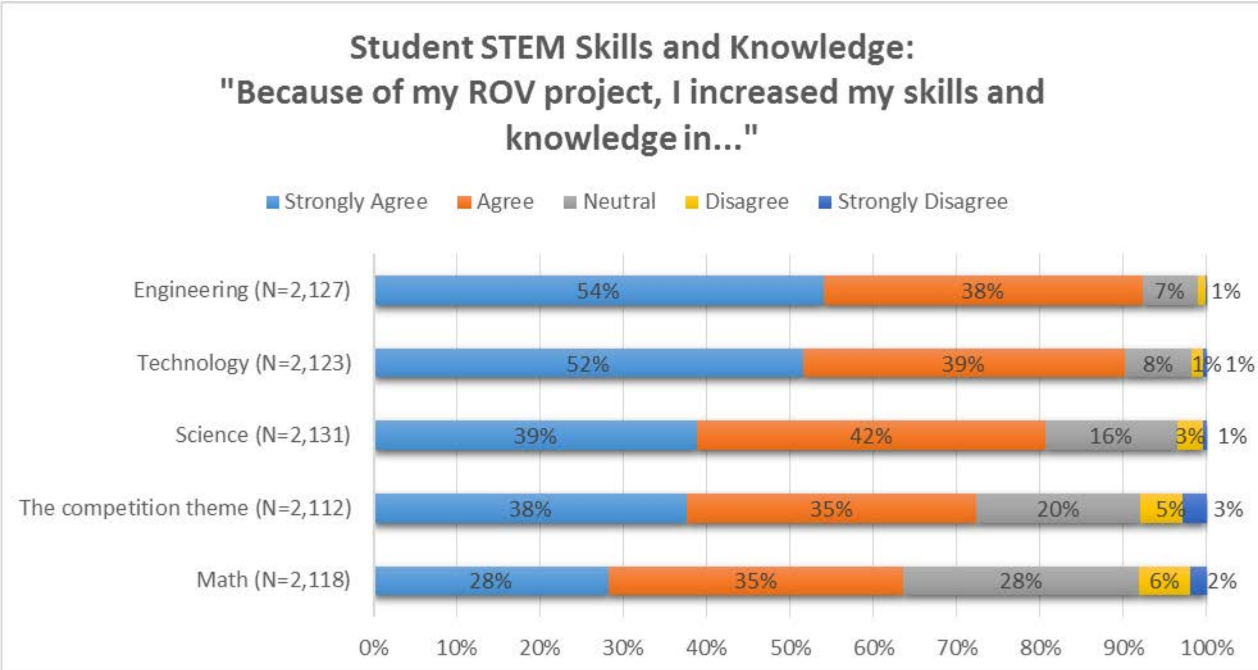
This competition made me twice as good as an electrical engineer.

I've learned about camera systems, mechanical frame designs, electrical system designs, and pneumatic system designs, etc.

This program has vastly improved my knowledge of engineering, technology, science, and teamwork skills.

It has strengthened my relationship with my team members and has made me improve my math, science and engineering skills.

Figure 4: Effect of ROV Project on Students' STEM Skills and Knowledge



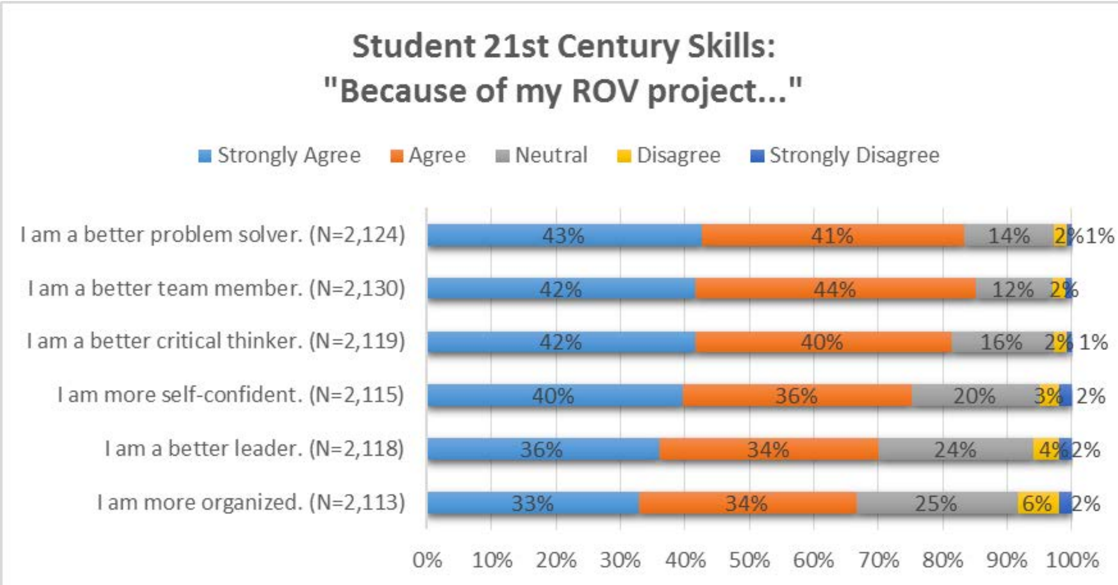
Among the teachers/mentors who completed post-competition surveys (N=342), 99% of the respondents reported that they observed improvements in their students' STEM knowledge and skills (66% strongly agreed, 32% agreed, 1.5% neutral, 0% disagreed or strongly disagreed).

Parents reported that building an ROV contributed to improving their children's grades in engineering/robotics (73%, N=335), science (57%, N=423), math (45%, N=421) and computers (54%, N=354).[3]

Increased 21st Century Skills: Students reported that participating in the ROV project improved their problem solving (84% agreed or strongly agreed, N=2,124), teamwork (85%, N=2,130), critical thinking (82%, N=2,119), leadership (70%, N=2,118), and organization skills (67%, N=2,113). Students also reported increased self-confidence (75%, N=2,115).

[3] Percentages are calculated among students studying each topic.

Figure 5: Effect of ROV Project on Students' 21st Century Skills



In responses to open-ended survey questions, students also described gaining 21st Century skills through their experiences building an ROV, such as the following:

> *My experience in this program helped me learn about communication and recognizing my skills as a team member. I am proud to represent my school and myself!*

> *I've grown as an adult because of this, which I needed, and value it very much.*

> *It made me a better leader and a more mature person.*

> *Though our robot didn't complete any mission task, I still learned a huge amount about project management, hands-on applications and working as a team.*

In the post-competition surveys, 99% of the teachers/mentors (N=341) mentioned that they observed increases in their students' skills in team building, problem solving, and/or critical thinking (60% strongly agreed, 38% agreed, 1% neutral, 0.3% disagreed, 0% strongly disagreed). Teachers/mentors saw skill development in many areas, as evidenced by their written comments:

> *We are amazed at the growth we have seen in our girls. Their confidence has grown, their knowledge of the engineering process has really grown, and I think [the MATE ROV competition at] Shedd…had a lot to do with that!*

This experience has allowed my students to grow individually and as team leaders. Thank you!

This is about so much more than robots. Students learn the 21st Century skills we always talk about in education but so rarely actually teach. Fantastic stuff.

My students learned to work well as a group and how to implement critical problem solving skills.

Parents were asked about their observations of changes in their children due to the ROV program. The vast majority agreed or strongly agreed that because of the ROV program, their children were better problem solvers (95%, N=431), critical thinkers (93%, N=423), team members (96%, N=431), and/or leaders (90%, N=429). Ninety percent (90%) of the parents (N=425) reported increased self-confidence in their children. In the open-ended comments, parents noted other changes that they observed in their children, including public speaking, leadership, prioritizing, working under pressure, resiliency, focus, time management, and self-confidence. Comments in this theme include the following:

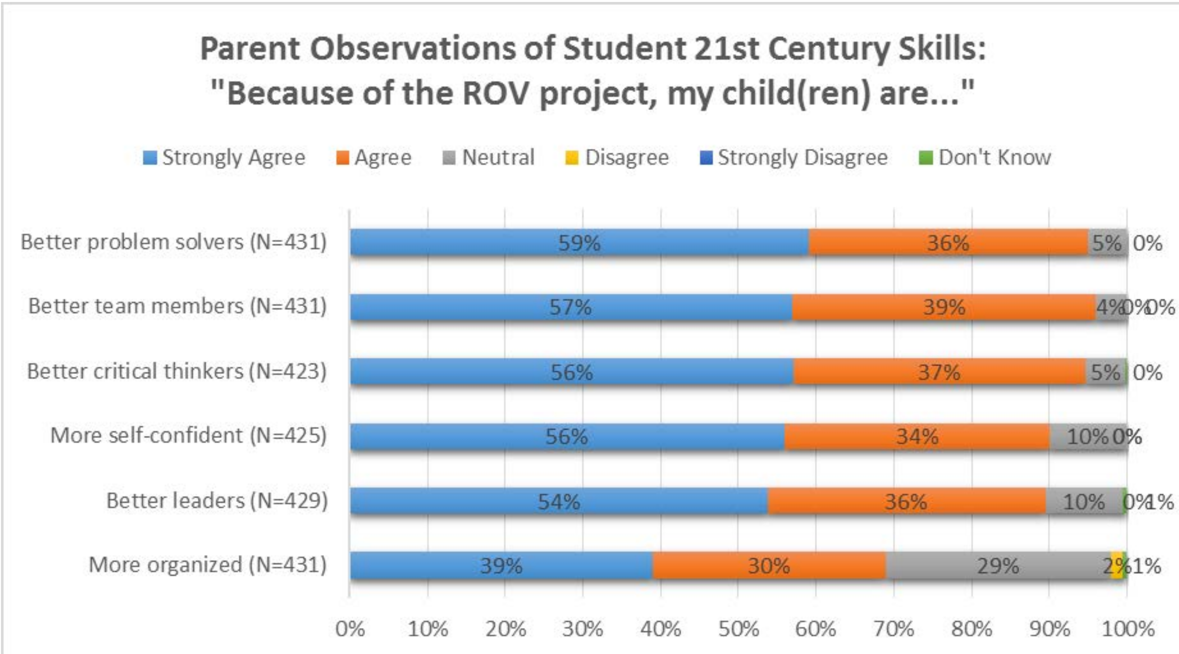
Wonderful to see him become more self-confident, independent and able to adjust to a variety of situations.

I have seen her become very determined and persistent to finish the project / very willing to work even on weekends or after dinner on her own.

He has grown immensely - self-confidence, maturity, even compassion - his team has even reached out to younger elementary students – He now considers himself a leader.

Her self-confidence has gone through the roof.

Figure 6: Parent Observations of Effect of ROV Competition on Students' 21st Century Skills

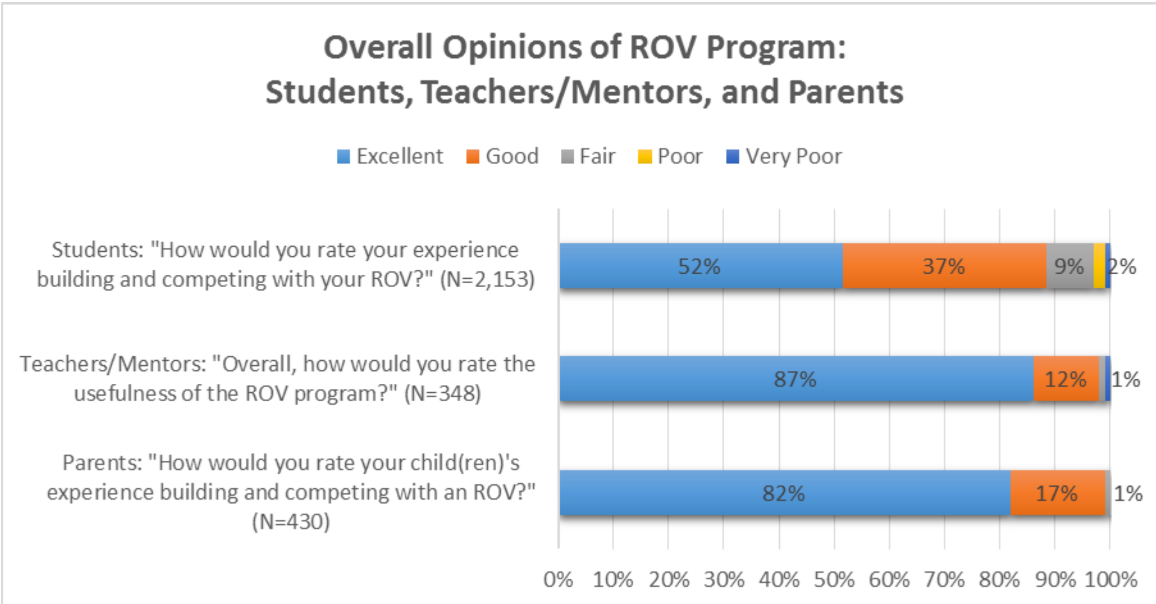


Overall Opinions of ROV Program: Overall, students (N=2,153) rated their experiences building and competing with their ROV very positively, with over half (52%) rating their experience as excellent, and 37% providing a rating of good. Nine percent (9%) thought their experience was fair. Two percent (2%) gave the experience a poor rating, and 1% rated it as very poor. (See *Figure 7*) In the post-competition surveys, students wrote comments such as the following:

> *This program opened my eyes to the world of technology and the use of courses such as math and science in the real world, which are not always taught in school. It made me a stronger team member as I needed to work with others to complete the task at hand and also a stronger leader which is useful both inside and outside the classroom. This opportunity has shown me all the possibilities of jobs surrounding technology, math and science out there.*

> *This program was a pleasure to take part in. I increased my overall knowledge in science, math, and engineering and had hands-on experience…that is very rare in other circumstances. I gained a greater knowledge of how to apply my skills to the real world because of this competition. It improved attributes such as teamwork, self-confidence, independence, and decision-making. This program helped me to develop in many ways, and I will be back for it again next year.*

Figure 7: Overall Opinions of the ROV Program from Students, Teachers/Mentors, and Parents



Teachers/mentors (N=348) gave nearly uniformly positive ratings of the usefulness of the competition, with 87% stating that it was excellent and 12% indicating that it was good (0.3% rated the competition as fair and 0.3% provided a rating of very poor.) Teachers/mentors also rated the support provided by the MATE program highly (58% excellent, 35% good, 6% fair, 0.3% poor, and 0% very poor). Teachers/mentors stressed the importance of the program in comments such as the following:

> *The program gives students opportunities to learn and apply many new skills (design, engineering, operations, project mgr., marketing) and communication / leadership, that they could never get in the classroom. They are better prepared for college and business or any career.*

> *Provides an excellent opportunity to develop practical skills to supplement conceptual learning. Develops soft skills - communication, team working, time and resource management. For pupils interested in STEM, the competition fired their imagination, and the problem-solving requirements provide superb contextualized problems and stimulate technological thinking.*

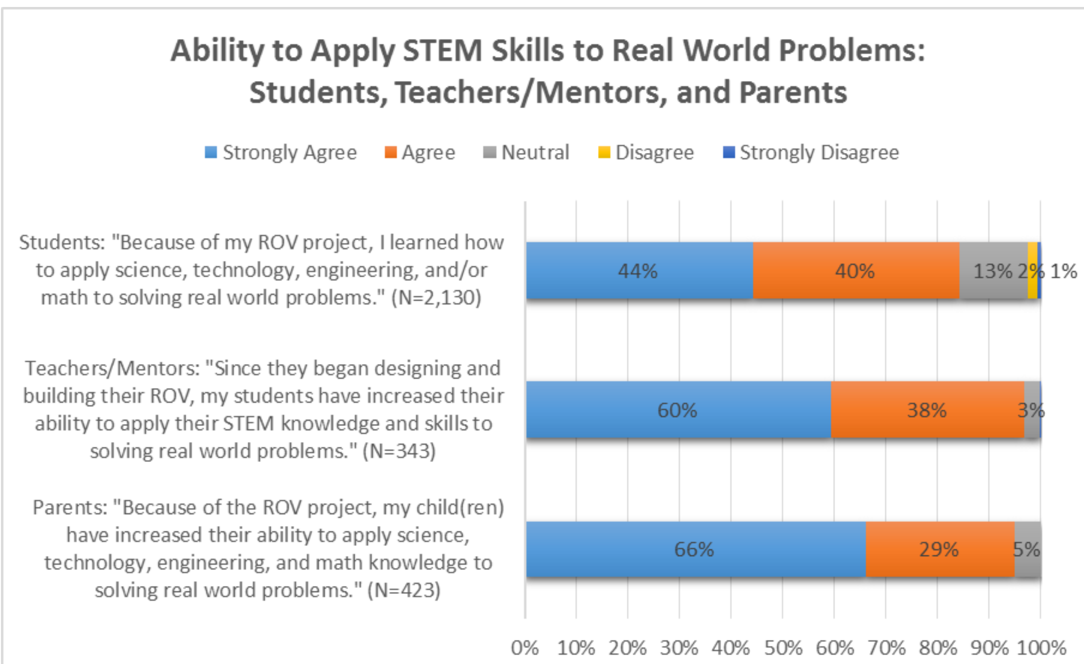
Overall, parents gave extremely positive ratings to their children's experience building and competing with an ROV. Eighty-two percent (82%, N=430) rated it as excellent, 17% gave a rating of good, 1% marked fair, and 0.2% were not sure. When asked whether the competition has been valuable for the educational development of their child, 82% strongly agreed that it was (N=430), 18% agreed with the statement, and 0.5% were neutral. No respondents disagreed or strongly disagreed.

> *Thank you! Involvement in MATE has literally been a life saver for our son. He was struck with a chronic disease 4 years ago. His [ROV] club meetings the past 3 years were, at times, the only activity he could manage to participate in. He would conserve his energy all week to make the meetings.*

Evaluation Question 1.2. How did the robotics activities affect students' ability to apply STEM knowledge and skills to finding solutions to real-world problems?

In the post-competition surveys, 85% of the students (N=2,130) indicated that participating in the ROV project helped them learn to apply STEM to real world problems. Ninety-seven percent (97%) of the teachers/mentors (N=343) observed improvements in their students' ability to apply STEM knowledge and skills to real world problems, as did 95% of the parents (N=423). (See *Figure 8*)

Figure 8: Effect of ROV Program on Ability to Apply STEM Skills to Real World Problems: Students, Teachers/Mentors, and Parents



Students recognized the connection between the competition and real-world application of their science and technology skills in the following quotes:

> *I loved the experience of taking an idea and making it a reality that can be applied to a real life scenario. Being able to apply knowledge learned in classes into real life is a very interesting experience.*

> *I really enjoyed working with my friends and having the opportunity to use my math skills in real life applications.*

Teachers appreciated the opportunities that the ROV projects gave for their students to apply their classroom knowledge to hands-on activities modeled after real-world problems, as evidenced in the following comments:

> *The MATE program is amazing and helps teachers provide exciting, real world STEM challenges that help focus students in problem solving, design, and engineering.*

> *Students applied their knowledge of science to design and build their ROV. This year we used pneumatics to operate a robotic arm. They used information from their grade eight science program. This allowed then to find a practical application for what they have learned. Great program, can't wait for next year.*

Parents also appreciated the real-world engineering industry focus of the competition, in comments such as the following:

> *Our child has always loved to build and knew he wanted to be an engineer, but this program has given him a PRACTICAL outlet to learn writing, programming and troubleshooting on a REAL project.*

Evaluation Question 1.3. How did the robotics activities affect students' ability to communicate their engineering process and designs to a wide audience (from engineers and technicians to the general public)?

Eighty-one percent (81%) of the students in the post-competition surveys (N=2,133) stated that participating in the ROV project helped them learn how to communicate their engineering design to other people.

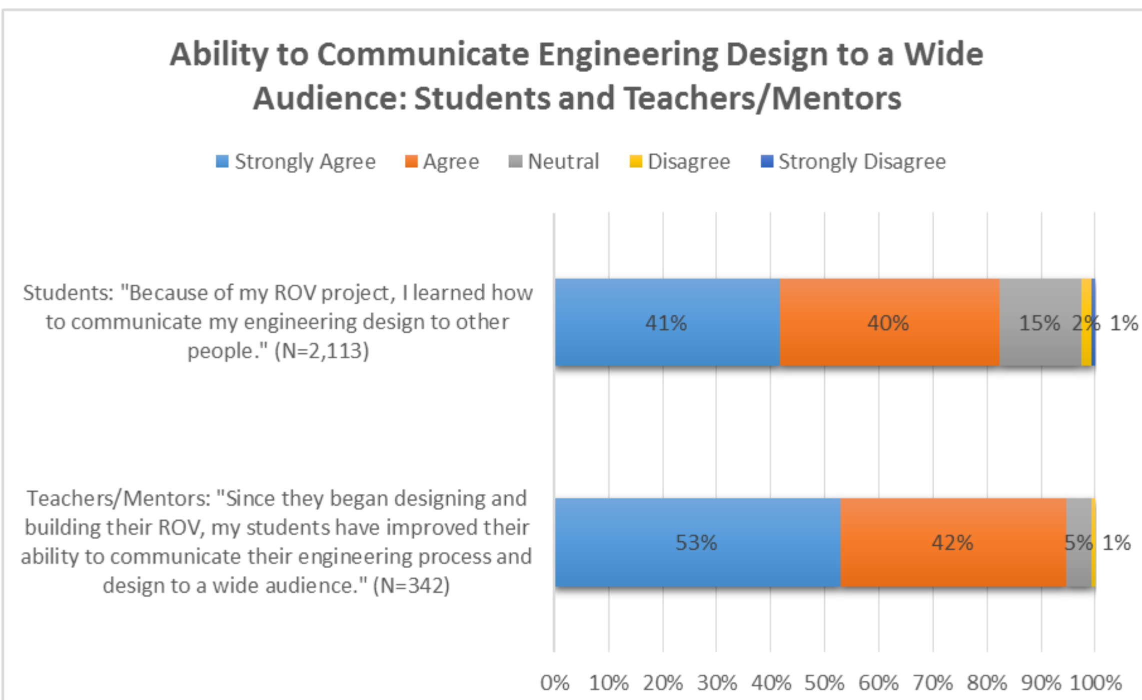
Ninety-four percent (94%) of the teachers/mentors (N=342) indicated that their students had improved their ability to communicate their engineering process and design to a wide audience. (See *Figure 9*)

Many students commented that their communication and presentation skills had increased, in quotations such as the following:

> *It helped me communicate with other people and learned more new things about engineering.*

> *My experience in this program helped me learn about communication and recognizing my skills as a team member.*

Figure 9: Effect of ROV Program on Ability to Communicate Engineering Process and Design



Evaluation Question 1.4. How did participation in the robotics activities influence students' educational and career paths?

ROV Competition Student Alumni Survey results include the following:

- 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%).

Please see the 2014-2015 evaluation report for further results from the ROV Competition Student Alumni Survey.

Evaluation Question 1.5. What effect did multi-year participation have on the above evaluation questions?

There were several statistically significant differences between the first year and multi-year competition participants. 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.

Specifically, multi-year participants were significantly more likely to report the following:

Table 5: Statistically Significant Differences between First-Year and Multi-Year Participants

	First-Year Participants: Percentage Strongly Agreeing	Multi-Year Participants: Percentage Strongly Agreeing
Increased awareness of STEM careers due to ROV program**	30.7%	36.7%
Increased interest in pursuing a STEM career due to ROV program*	41.2%	46.3%
Learned how to apply STEM knowledge to solving real world problems due to ROV program**	41.5%	49.3%
Learned how to communicate their engineering designs due to ROV program**	39.0%	44.5%
Want to learn more about STEM topics*	48.1%	53.5%
More interested in taking engineering courses due to ROV program**	39.7%	47.8%
More interested in taking science courses due to ROV program**	33.1%	41.1%
More interested in taking math courses due to ROV program*	26.9%	31.3%
Increased skills and knowledge in engineering due to ROV program*	51.4%	57.2%
Increased skills and knowledge in science due to ROV program*	36.7%	42.6%
Increased skills and knowledge in math due to ROV program**	25.7%	32.1%

Increased leadership skills due to ROV program**	32.3%	43.2%
Increased problem solving skills due to ROV program*	41.5%	45.8%
Increased critical thinking skills due to ROV program*	40.7%	44.0%
More interested in a STEM career*	78.9%	82.6%
Received an award or honor due to ROV program**	26.3%	45.4%
ROV program participation opened educational or career opportunities**	31.0%	44.9%

* $p < 0.05$

**$p < 0.01$

DEMOGRAPHIC BREAKDOWNS OF FIRST-YEAR AND MULTI-YEAR PARTICIPANTS

There were no statistically significant differences between the first-year and multi-year participants in gender (first-year: 71% male; multi-year: 73% male) or ethnicity (first-year: 61% white; multi-year: 59% white). The first-year participants were significantly more likely to live in a low socioeconomic status neighborhood (first-year: 43%, multi-year: 34%).

Compared to the multi-year participants, a greater proportion of the first-year participants were in the SCOUT (entry-level) competition class (first-year: 38%, multi-year: 20%). The bulk of the multi-year students were in the RANGER (intermediate) class (first-year: 41%, multi-year: 55%) and NAVIGATOR (beginner-intermediate) class (first-year: 9%, multi-year: 13%). Twelve percent (12%) of both groups were in the EXPLORER (advanced) competition class.

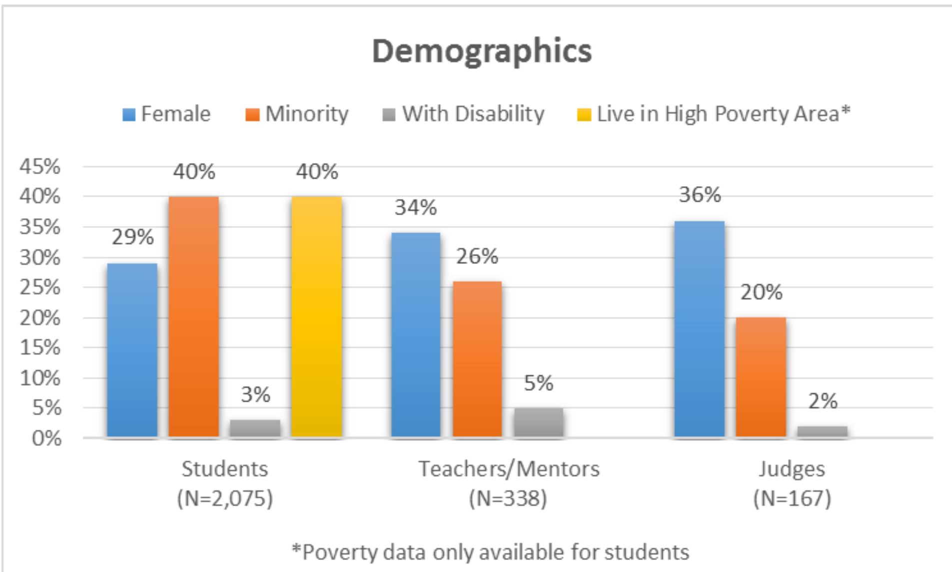
The first-year participants did not differ significantly from the multi-year participants according to disabilities requiring accommodations (first-year: 2.7%, multi-year: 2.5%).

Evaluation Question 1.6. Did the robotics activities create the same impacts among underrepresented groups (by gender, ethnicity, socio-economic status, disability) as were found among students who traditionally participate in these types of activities?

BACKGROUND: DEMOGRAPHICS OF STUDENTS, TEACHERS AND INDUSTRY REPRESENTATIVES

According to the demographic data in the surveys, the students were over one-quarter female (29%, N=2,075), 40% percent were of minority backgrounds [4], 40% came from high poverty areas[5], and 3% reported that they had disabilities requiring accommodations. (See *Figure 10*)

Figure 10: Student, Teacher/Mentor, and Judge Demographics



The project has made efforts to include the participation of teachers, college students, staff, and competition judges (industry professionals) of diverse backgrounds who can serve as role models for the

[4] The sample size of participant surveys from each ethnicity was not large enough to do analysis by individual ethnicity. Instead, all non-white respondents were coded as "minority", and results were analyzed by this "minority status" variable.

[5] High poverty areas were defined as zip codes where the percentage of families with children under age 18 in poverty was higher than the nationwide average of 18.1%. This calculation is based on data from the 2014 American Community Survey at the ZTCA level.

middle school students. About one-third (34%) of the teachers (N=338) were female, 26% were of minority backgrounds, and 5% indicated that they had a disability.

Among the judges completing surveys (N=167), 36% were female, 20% were of minority ethnic backgrounds, and 3% marked that they had a disability.

ANALYSIS

As the MATE Center is a longstanding center, the evaluation has improved over time. In the 2009-2010 evaluation report, preliminary results presented the trends by gender and ethnicity only. In 2010-2011, the analysis took a different approach. Rather than simply look at trends, the changes in survey administration methods helped us produce a dataset more suitable for more sophisticated analysis. Thus, we looked for statistically significant differences between the under-represented students and the students who more typically participate in these types of STEM events.

This new analysis begged the question: how should success be defined? In consultation with project managers, the evaluators decided that the measure of successfully engaging under-representative students would be that their results were not statistically different from the other students' results. In other words, the under-represented students made the same gains as the other students.

FINDINGS BY STUDENT DEMOGRAPHICS

The analysis focuses on whether there were statistically significant differences between the groups (gender, ethnicity, socioeconomic status, and disability status) in the following topics:

- Awareness of and interest in STEM careers
- Interest in STEM topics
- STEM skills and knowledge

Statistically significant differences existed between the groups in the following measures:

Awareness of and Interest in STEM Careers

- **Gender:** Between the male and female students, there were no statistically significant differences in gains in knowledge about STEM careers (male: 33% strongly agreed, female: 31% strongly agreed); however, male students were significantly more likely to cite the competition as influencing them towards a STEM career (male: 47% strongly agreed; female: 35% strongly agreed).
- **Ethnicity:** There were no significant differences in gains in knowledge of or interest in STEM careers by ethnicity.

- **Socioeconomic status:** There were no statistically significant differences by socioeconomic status in the gains in knowledge about STEM careers. Students living in high poverty areas were less likely to indicate that the competition led to gains in their interest in STEM careers (low poverty: 47%; high poverty: 41%).
- **Disability status:** There were no significant differences in gains in knowledge of or interest in STEM careers by disability.

Interest in STEM Topics

- **Gender:** Male students were more likely to report increased interest in computer science (male: 42% strongly agreed, female: 30% strongly agreed), math (male: 29%, female: 27%) and engineering (male: 45%, female: 35%) courses. There were no significant differences between the genders in the interest in taking science courses or hands-on classes or clubs like robotics, electronics, or shop.
- **Ethnicity:** White students were more likely to report increased interest in engineering courses (white: 55% strongly agreed; minority: 51% strongly agreed).
- **Socioeconomic status:** Students in high poverty areas were more likely to indicate that the competition increased their desire to take hands-on classes or club activities (low poverty: 59%; high poverty: 64%). There were no significant differences between the responses of the students living in high and low poverty areas in the increased interest in other STEM topics.
- **Disability status:** Students with disabilities were more likely to report increased interest in computer science courses (students with disabilities: 42%, students without disabilities: 39%). Students without disabilities were more likely to report increased interest in taking hands-on courses or club activities (students with disabilities: 56%, students without disabilities: 58%). There were no significant differences between the responses of the students with and without disabilities in regards to interest in other STEM courses.

STEM Skills and Knowledge

- **Gender:** Male students were more likely than female students to report increased skills and knowledge in engineering (male: 55% strongly agreed, female: 49% strongly agreed) and technology (male: 54%, female: 48%). There were no significant differences by gender in gains in knowledge in science, math, or knowledge about the competition theme.
- **Ethnicity:** White students were more likely to strongly agree that due to the ROV competition, they increased their skills and knowledge in engineering (white: 55%; minority: 51%). There were no significant differences by ethnicity in the increased skills in other STEM topics.
- **Socioeconomic status:** Students living in a higher poverty area were more likely to report gains in skills and knowledge in the competition theme (low poverty: 37%, high poverty: 43%). There were no other significant differences in the STEM skills and knowledge according to socioeconomic status.

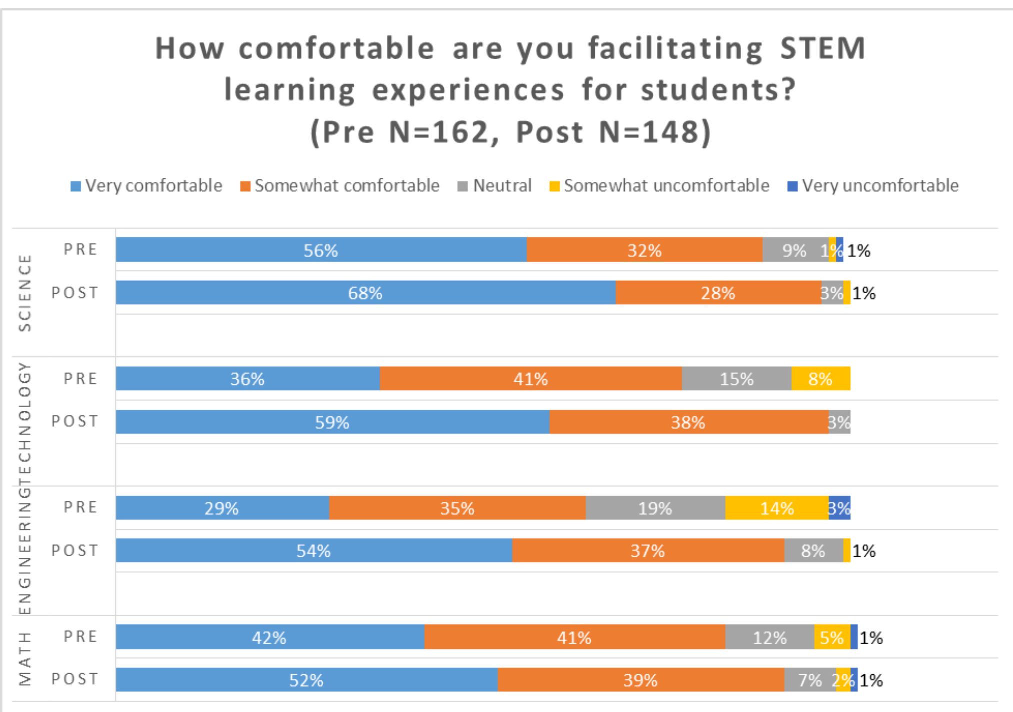
- **Disability status:** Students without disabilities were more likely to report increased skills and knowledge in science (students with disabilities: 38.9%, students without disabilities: 39.2%), math (students with disabilities: 56%, students without disabilities: 26%), and technology (students with disabilities: 44%, students without disabilities: 53%). Students with disabilities were more likely to report increases in knowledge about the competition theme (students with disabilities: 39%; students without disabilities: 38%).

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

Evaluation Question 2.1. Are teachers more confident delivering STEM learning experiences? Delivering career information and outlining career pathways?

Pre and post workshop surveys, post competition surveys, and Summer Institute feedback surveys demonstrate that the participants gained confidence facilitating STEM learning experiences through the training and support provided by MATE. The percentage of respondents who rated themselves as “very comfortable” facilitating STEM learning experiences for students rose between the pre and post workshop surveys for science (pre: 56%, post: 68%), technology (pre: 36%, post: 59%), engineering (pre: 29%, post: 54%), and math (pre: 42%, post: 52%).

Figure 11: Level of Teacher Confidence Facilitating STEM Learning Experiences: Pre and Post Workshops

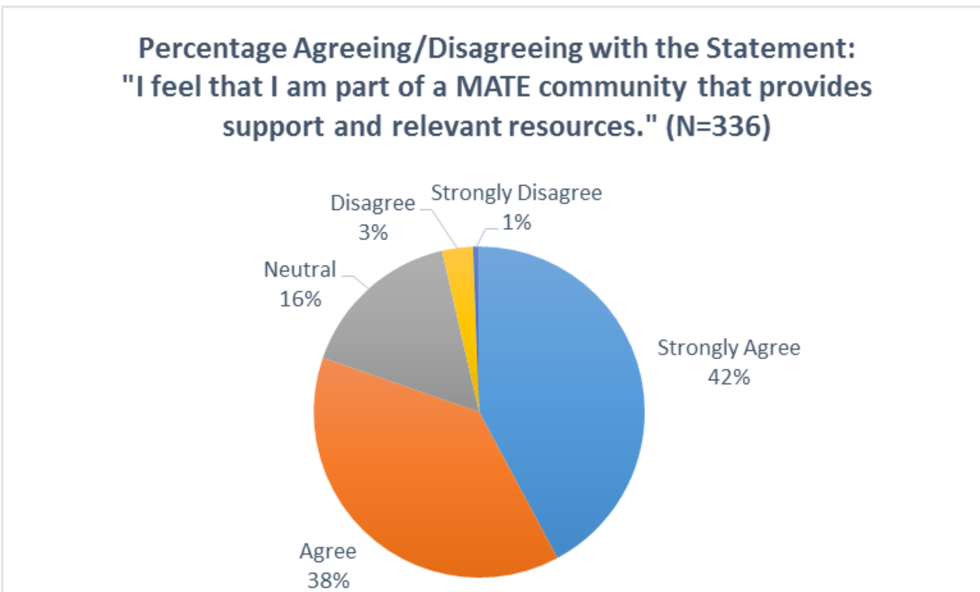


Evaluation Question 2.2. Do teachers feel they are a part of a larger MATE community that provides support and relevant, necessary resources?

Among the post-competition surveys, 80% of the teachers (N=336) agreed that they felt they were part of a MATE community that provides support and relevant resources. Sixteen percent (16%) felt neutral about the statement; 3% disagreed, and 0.6% strongly disagreed. In the post-competition surveys, one teacher provided the following comment about the impact that the ROV program has had on him or her:

> *As a teacher, I feel that the ROV program has given me something important to add to my portfolio. Additionally, I have met colleagues with similar interests and I have become part of a network of ROV enthusiasts.*

Figure 12: Percentage Agreeing/Disagreeing that They Feel a Part of a MATE Community



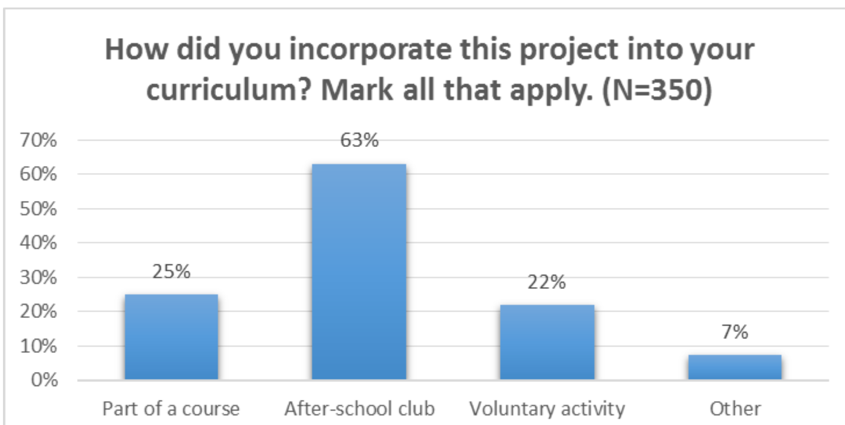
Evaluation Question 2.3. Do teachers incorporate MATE robotics activities/curriculum into courses and afterschool programs? Are the courses and/or curriculum adopted by school districts?

In the post-competition surveys, over three-quarters (81%) of the teachers (N=312) stated that they used MATE materials and resources to incorporate ROV building into their course or club, and over half (63%) modified their curriculum and teaching based on MATE resources. One teacher explained how she incorporated the competition components and rubrics into his or her classroom:

> *The ROV program itself is great, the robot, the tech paper and poster, the engineering evaluation. We incorporate those components into an Intro to Robotics and Advanced Robotics classes, and use your MATE poster and tech paper rubrics, (modified to our class specs).*

Sixty-three percent (63%) of the post-competition survey respondents (N=350) incorporated building ROVs into an after-school club. Twenty-five percent (25%) built ROVs as part of a course; 22% built ROVs as a voluntary activity; and 7% built ROVs in another venue.

Figure 13: ROV Projects in Courses, After-School Clubs, Voluntary Activities, and Other Activities



In the teacher post-workshop surveys, 30% of the respondents (N=148) were planning to incorporate ROVs into 48 courses in the school system. According to the teachers, these courses fall into the categories of engineering, science, technology, physics, math, career and technical education, and career pathways. The course names include the following, as written by the respondents:

- Underwater/Marine Robotics
- Underwater Robotics Seminar
- Underwater Robotics
- Underwater Robotics
- STEM Apps 2 and 3
- STEM
- ROV Technology
- Robotics, Unleashed
- Robotics
- Pre-engineering
- Physics, P.S. with Technology
- Physics
- Physical Science, Marine Biology, Algebra, Geometry
- Physical Science, Biology, Marine Biology
- Physical Science, Physics A/P
- Mathematics
- Marine Bio
- Intro to Robotics
- Intro to Engineering
- Industrial Engineering Core
- IET Course
- IET core / Business core
- Environmental Science & Architecture/ Engineering
- Environmental Science
- Engineering 1
- Engineering & Design (Beyond)
- AP Bio / AP Environmental
- Algebra 1
- 6 weeks UOI IB Exploration Unit

In the one-year follow-up survey of the week-long, intensive 2015 Pufferfish Summer Institute, 17 of the 18 participants built ROVs with students. A total of 281 ROVs were built with 1,228 students. Eight (8) of the ROVs were used in the 2016 MATE ROV competition.

Evaluation Question 2.4. Are teachers able to access classroom mentors as needed? Do the classroom mentors help them successfully incorporate robotics activities into the course? Are the classroom mentors adequately prepared?

In several regions, the regional coordinator matched up college and high school students – in many cases, former ROV competitors themselves – with middle school ROV teams to work with them throughout the competition season. College students also acted as helpers at the workshops. In some cases, the college students received a small stipend (though they stated that they would have done the work without it), and in other cases they received service learning credit, Presidential Volunteer Service Awards, or simply volunteered their time with no recompense. This arrangement worked well for the regional coordinators, college students and middle school students and teachers.

Anecdotal reports suggest that the involvement of college students as mentors can lead to profound experiences for both the college and middle school students. Many sources reported that the middle school students found the college students to be approachable representatives of science. These young adults modeled the paths that the middle school students could take to a STEM career.

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 extent” for 57% of the respondents, a “moderate extent” for 30% of the respondents, and a “small extent” for 7% of the respondents; 1% stated that the mentors were not helpful at all, and 4% were not sure.

Most of the respondents (96%) indicated that their mentors were adequately prepared to help them and their students through the ROV design and building process. Two percent (2%) marked that the mentors were not adequately prepared, and 2% were unsure.

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

Evaluation Question(s) 3.1. Did the MATE robotics activities lead to an increase in the parents' support of their children's interest in STEM careers?

Ninety-four percent (94%) of the parents surveyed (N=425) agreed or strongly agreed that participation in the ROV program changed how they envisioned their child's future, making it easier to picture their child with a STEM career (69% strongly agreed, 25% agreed). Six percent (6%) were neutral, and 0.2% percent disagreed. No respondents strongly disagreed.

Evaluation Question 3.2. Did the enhanced parent online resources lead to an increase in the parents' ability to provide assistance and support for their children's involvement in the MATE robotics activities?

The online Parent Resource Center (http://www.marinetech.org/parent-resource-center) was launched in the spring of 2015. It contains competition videos, frequently asked questions, background information, highlights, and contact information for the MATE Center, along with types of information that the MATE Center can provide upon request. Anecdotal evidence indicates that parents found the resources to be helpful, such as comments such as the following:

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

> *This was a great first year. The online resources were very helpful.*

Evaluation Question 3.3. Did the regional parent advisory committees provide feedback and advice to help improve the competitions and ensure that the program is inclusive of all participants?

Advisory committees were broadened to invite participation from parents as well as industry representatives, professional organizations (e.g., Marine Technology Society), government agencies (e.g., NOAA) 6-12th grade educators, community college faculty, and university faculty. The committees were implemented at the regional level so the recommendations would be applicable to the local community needs.

In 2015-2016, some regions held an annual advisory meeting (e.g., Gray's Reef and Buckeye Regions), while others held monthly advisory meetings (e.g., Florida Region), or communicated on an ongoing basis with advisory members outside of formal meetings (e.g., Oregon, New England, Great Lakes, and Wisconsin Regions). Advisory groups communicated face-to-face, and via video meetings (e.g., ZOOM), email, and web surveys. Advisory committees provided recommendations in the following areas:

- Timing and content of workshops and regional events
- Funding sources
- Outreach
- Associated activities during competition

The regional coordinators were responsive to their committees' recommendations.

Broader Impacts

The MATE Center's ITEST activities have been leveraged by regional coordinators and participants in ways that were unanticipated during the writing of the proposal. Thus, they don't fit under any particular evaluation question. Since the evaluation was not set up to monitor these activities, the findings presented here should be considered preliminary. Next year, the evaluation tools will be modified to capture more of this data.

These "broader impacts" fall into three main categories:

1. Leveraging ITEST activities/funding to raise additional funding by regional coordinators, teachers, schools, and student teams;
2. Using ROVs and ROV-based activities outside of the competition by teachers and students;

3. Broader impacts on teachers and institutions: new careers, new classes, deeper relationships with students, improved STEM knowledge, increased motivation and engagement with their discipline, and increased professional development opportunities.

LEVERAGING ITEST ACTIVITIES/FUNDING

Faculty who led ROV teams and/or attended the Summer Institute reported that they have applied for and won funding from grants and school boards and have received equipment donations from local industry. Additionally, ROV competition regions outside of the United States have leveraged news of the ITEST grant to raise additional funds.

USING ROVS OUTSIDE THE COMPETITION

Many faculty have reported using ROVs or ROV-based activities outside of the competition, incorporating these tools and topics into their classes or clubs in order to bring science to life.

BROADER IMPACTS ON TEACHERS AND INSTITUTIONS

Teachers report a broad variety of positive results from their participation in the ROV competition and professional development, including the following:

- New careers
- New classes
- Deepened relationships with students
- New collaborations with industry, research orgs, and other educational institutions
- Improved STEM knowledge
- Increased motivation and engagement with their discipline
- Increased professional development opportunities (in addition to that offered by MATE)

CONCLUSIONS

Overall, the MATE Center successfully implemented the 2015-2016 year of ITEST grant activities. The 2016 MATE ROV Competition was held, with ITEST funding helping to support 15 of the 18 US-based regional events. A total of 290 regional workshops were held for teachers and students, and 20 teachers attended the intensive Summer Institute professional development. The focus on a formal curriculum was changed to development of a suite of online instructional materials, which were disseminated, including videos, PowerPoints, ROV kits, and an online course.

The evaluation's student follow-up efforts made progress in several areas. The alumni survey was completed in 2015. The Washington State Follow-up slowed due to communication issues with ERDC; though we expect that the study will move forward in the next year. The National Student Clearinghouse data match is in process. The collaboration with Dr. Li from the University of Washington continues to produce improvements to the survey instruments and competition scoring rubrics and manuals.

Overall, evaluation results continue to show strong positive outcomes for students and teachers. Involvement in the ROV competition generated greater awareness of and interest in pursuing STEM careers, increased interest in studying STEM topics, improved STEM knowledge and skills, and increased 21st Century skills, including teamwork, critical thinking, leadership, problem solving and self-confidence. Participating in the ROV competition helped students learn how to apply STEM skills to real world problems. Students also learned how to communicate their engineering process and design to a wide audience.

Parents were passionate supporters of their children's involvement in the program, with comments such as, "Thank you! Involvement in MATE has literally been a life saver for our son." Educational research has stressed the importance of family support in a student's choice to follow a STEM career path. Evaluation results show that the ROV program impacted the participants' parents as well, making it easier for them to picture their child in a STEM career.

As stated in the 2014-2015 evaluation report, ROV competition student alumni survey results suggest that the majority of ROV competition participants go on to study STEM topics, earn STEM degrees, and work in STEM fields. In fact, roughly one in five former participants have worked in a job related to ROVs or other underwater technologies. The majority of ROV competition alumni credit the ROV competition with influencing their educational and career paths, including playing a role in attaining internships, scholarships, admittance to educational programs, and employment.

These findings suggest that the MATE ROV Competition is effective in increasing the STEM workforce, especially related to underwater technologies. As one parent stated:

My son has a learning difference, yet despite this, he actively participated, supported his team, and was supported by them. Our team of no college graduate parents envision themselves as future engineers.