AC 2011-1186: THE VIRGINIA DEMONSTRATION PROJECT–A SUMMATIVE ASSESSMENT

Jacob D. Joseph, The College of William and Mary

Jacob Joseph has over ten years of experience in the engineering industry, and has taught secondary chemistry and physics. Mr. Joseph is the Virginia area coordinator for the STEM Education Alliance. In addition, he is currently the lead evaluator on a Department of Defense grant and is lead on the evaluation team designing the new survey instrument, the STEM Attitudes and Awareness Scale.

Jessica Taylor, STEM Education Alliance, College of William and Mary

JESSICA TAYLOR- Jessica Taylor is a Program Coordinator for the STEM Education Alliance. She serves as a professional development coordinator, curriculum developer, and outreach liaison to the Virginia Demonstration Project, a program supported by the Department of Defense. She has worked in various formal and informal science education programs since 2001.

Gail B. Hardinge, STEM Education Alliance - College of William and Mary

GAIL B. HARDINGE - Gail Hardinge is a Clinical Associate Professor of Education at the College of William and Mary. She is the director of the STEM Education Alliance, a project center designed to create connections between the educational, science and engineering communities. She is the project director for the Virginia Demonstration Project, a Department of Defense funded initiative that has received several Virginia science awards. She teaches educational consultation and assessment, and supervises advanced graduate students in field studies.

Eugene F. Brown, Virginia Tech

EUGENE BROWN Eugene Brown is Professor of Mechanical Engineering at Virginia Tech. He has worked with ONR and DoD since 2001 on educational-outreach-related work-force development issues. He teaches undergraduate and graduate courses in thermodynamics and fluid mechanics and is the author of many papers and reports describing his research in the areas of computational fluid dynamics, fluid mechanics, and his work in educational outreach.

©American Society for Engineering Education, 2011

The Virginia Demonstration Project—
A Summative Assessment

Introduction

The Virginia Demonstration Project (VDP) is a middle-school-focused, educational outreach program that is designed to increase the interest of middle-school students in STEM (Science, Technology, Engineering and Math) careers. This is accomplished by exposing the students to real-life, problem-based challenges, solved in a cooperative learning environment and stimulated by lesson plans collaboratively implemented by their classroom teacher and visiting Navy scientists and engineers (S&Es). It makes science and math connections between the classroom and real life, supplies students with information on careers in science and engineering, and provides the students' career gatekeepers (teachers, family, and counselors) with the information that is needed to communicate accurately with them about preparing for STEM careers.

This paper provides information on an assessment of the VDP's Academic Year and Summer Academy programs that measures the impact of these programs on students' attitudes toward science and math, their sense of self-adequacy, and their interest in pursuing STEM careers.

Project Description

In the fall of 2003, representatives from the Office of Naval Research met with then Senator John Warner's staff (R-VA) to seek funding for an innovative program devoted to increasing the interest of middle school students in pursuing careers in science and engineering. The VDP emerged from these discussions and has grown to reach more than 3,700 7th and 8th graders and170 science and math teachers in 27 schools and 5 states. Nearly 100 Navy S&Es are involved in the program who work side-by-side with classroom teachers to engage students in real-world, problem-based activities and to function as facilitators, mentors, content providers, and role models. The program receives its support through a partnership with the National Defense Education Program (NDEP) and the Office of Naval Research (ONR) and is operated by the STEM Education Alliance of the School of Education at the College of William and Mary (http://stem.wm.edu/about/).

The center of the activity is with the five school systems that surround the Naval Surface Warfare Center in Dahlgren, VA (NSWCDD)— the public school systems of Caroline, King George, Spotsylvania, and Stafford counties and the city of Fredericksburg—plus the public school systems of Accomack county and the city of Portsmouth. In recent years the program has grown beyond these seven systems to include school systems located at the Naval Sea Warfare Centers in Dam Neck, VA, Indian Head, MD, and Philadelphia, PA. In addition, there are elements of the VDP at the Space and Naval Warfare Systems Command in Charleston, SC, and at the Air Force Research Laboratory Information Directorate in Rome, NY. From its inception, the VDP has featured significant involvement by Navy S&Es who serve as co-teachers, mentors, and role models in the academic year and summer portions of the program.

The mission of the VDP is to: (1) increase the numbers of domestic students, particularly students from under-represented groups, pursuing STEM degrees by enhancing student interest in and attitudes toward math and science, (2) strengthen peer, family and school support for such interests, (3) ensure long-term inclusiveness of women and minorities in STEM programs, and (4) increase the number of students taking advanced-level mathematics and science courses. By increasing students' interest in STEM content in their middle-school years, the intention of the VDP is to inspire students to become the next generation of scientists and engineers.

The VDP consists of Academic Year, Summer Academy, and National Outreach programs.

Academic Year Program—The VDP's Academic Year Program is an inclusive, in-class initiative involving approximately thirty contact hours. Teachers and S&Es collaborate on the delivery of a high-energy curriculum, *R2: Relevant Robotics,* designed to leverage the efficacy of research-based educational techniques, developed around a *Five Strands of STEM Instruction* model. The *R2: Relevant Robotics* curriculum consists of two units, "Crisis at a Coral Reef" and "Landmines," both of which are correlated to national math and science standards. Information about the content of both units can be found at http://stem.wm.edu/teacher-resources/r2-curriculum-modules/

In the "Crisis at a Coral Reef" module, students are faced with a situation in which a ship has run aground on a tropical coral reef and is leaking oil. This oil leak threatens the reef's organisms, its ecosystem, and the livelihoods of the local residents. Robots are used to rescue animals, to deliver environmental containment and cleaning supplies, and to provide humanitarian relief to the villagers.

In the "Landmines" module, a minefield at sea has been disrupted by a tsunami that has swept the mines onto the shore. Some mines are visible, and others are hidden under sand and debris. Robots help mitigate the disaster by locating landmines and delivering humanitarian aid.

Fig 1. A Summer Academy Challenge

Summer Academy Program—The Summer Academy Program is a week-long, day-time summer camp held at NSWCDD, for which students are nominated by their teachers and parents to attend. The focus is on a suite of robotics challenges that are similar in format to, but more advanced in content than, the Academic-Year "Crisis at a Coral Reef" and the "Landmines" modules. These robotics challenges are supplemented by short (break-out) ballistics, rocketry, electronics, biology, chemistry, and environmental science experiments. These experiments were chosen based on the desire to provide a selection of projects that would demonstrate a wide variety of science- and physics-based phenomena, involve appropriate math and problem solving tasks, provide team-building opportunities, and be of interest and provide enjoyment to a diverse group of students, both with regard to gender and ability. Workbooks that describe typical Summer Academy robotic challenges and breakout experiments can be found at http://stem.wm.edu/teacher-resources/r2-curriculum-modules/.

Fig. 2. The 5 Strands of Effective STEM Instruction

National Outreach Program—In order to ensure both the effectiveness and fidelity in the implementation of the program, professional development training is provided by the STEM Education Alliance to both teachers and S&Es. As an outgrowth of this, the Alliance now provides program consultation, professional development training, and management assistance for military installations and school systems across seven states.

Guiding the professional training which the Alliance provides, is the *5 Strands of Effective STEM Instruction* that is based upon an extensive review and consideration of the educational literature and many years of accumulated teaching experience. The *5 Strands of Effective STEM Instruction* is composed of five content and instructional strands (Inquiry Learning, Co-Teaching, Explicit Instruction, Cooperative Learning, and Thematic/Big-Idea Instruction) that provide a best-practice approach to STEM education in the K-12 setting.

The professional development program is hosted by the individual school divisions and amounts to approximately a day and a half of instruction. Both the teachers and the S&Es that the teachers will be working with participate in the program together. This is a relationship building process in which the S&Es become more aware of teacher/education issues and the teachers learn more about the S&Es' work environment, the projects they work on, and their professional training. The professional development program is divided into: VDP overview, the Five Strands of Effective STEM Instruction, Integrating STEM Career Connections, Climate and Ethics, LEGO Robotics Building and Programming, VDP Curriculum and Activities, Program Evaluation, and Implementation Plan.

Assessment

The purpose of the assessment process described here is to measure the changes in student attitudes, awareness, and knowledge of STEM and STEM careers as a result of participating in the Academic Year and Summer Academy portions of the VDP.

It is our hope that this paper, which presents what the Alliance has done (with very modest funds) in the way of assessing its Academic Year and Summer Academy programs, will provide the encouragement and incentive for others to make assessment an important part of their outreach programs.

Academic Year Program—The evaluation was a one-group, pre-test/post-test study involving students in the public school systems of Stafford, Spotsylvania, King George, Caroline, Portsmouth, Accomack counties and the city of Fredericksburg. The population, by race, consisted of 56% Caucasian, 22% African American, 6% Hispanic, 6% Asian, and 10% Other. The data was drawn from a total of 4,117 students. Instruction was provided by a total of 133 teachers and 31 S&Es. The students included in the final analysis were evenly divided by gender and grade level (7th and 8th).

A multidimensional analysis of the changes in student beliefs, knowledge, attitude, and awareness was conducted using a project-developed instrument, the *STEM Student Awareness and Attitude* Scale (STEM SAAS) with the results being collected both in web-based and hard-copy form. A copy of the assessment instrument appears in the Appendix.

The data was first inspected to remove spurious and incomplete responses. The data removed included surveys where students responded with the same, say the first, answer to all questions, where students failed to respond to the validation question correctly, such as, “Select the third response to this question,” or where the students’ responses formed a “seasonal” pattern, such as a Christmas tree. Before data cleansing, there were 2,065 completed pre-surveys and 1,796 completed post-surveys. After data cleansing, there was a total of 803 matched pairs of pre-test and post-test surveys. In addition, questions that were not directly related to project and evaluation goals were removed. The remaining questions were then grouped into eight factors.

A second factor analysis was then carried out with a reduced (six rather than eight) number of factors that decreased the number of factors that loaded on multiple items. The factors that were used in the subsequent analysis were: (1) Building and Invention, (2) Interest in Pursuing Stem Career, (3) Science Attitudes, (4) Technology Attitudes, (5) Math Attitudes, and (6) Stem Career Awareness. The questions of which these factors are composed appear in the Appendix along with the maximum and minimum scores obtained for each factor, calculated by a summation of the Likert scale responses to each question.

Using the factor summation as defined above, a matched-pair t-test was performed on the 803 samples. The results for the individual factors are provided in the table below:

Factor	Pre-Value	Post-Value	Out of Possible	2-Tailed Significance
Building and Invention	17.44	17.46	25	.816
Interest In Pursuing Stem Career	14.32	14.78	25	.000
Science Attitudes	11.97	11.90	15	.256
Technology Attitudes	19.87	19.80	25	.557
Math Attitudes	14.62	14.86	20	.002
Stem Career Awareness	7.34	7.49	10	.017

In general, there was a statistically significant difference in the students' reporting of their interest in pursuing a STEM career after participation in the VDP. In addition, the students' self-reported attitudes toward math and likelihood of pursuing a STEM career increased after participation in the program. This is shown in Figure 3. However, there were no significant changes found in the Building and Invention, Science Attitudes, or Technology Attitudes factors as a result of participation in the program.

The data for the entire group of 7th and 8th graders largely reflects the data for each subgroup with a few notable exceptions. The entire group of 7th grade students showed no statistically significant differences between pre- and post-interventions. In addition, Hispanic students and Asian-American students showed no statistically significant pre-test/post-test differences. The data for female students showed a statistically significant increase in self-reported math attitudes, STEM career awareness, and interest in pursuing a STEM career, whereas the data for male students showed only a statistically significant difference in intent to pursue a STEM career.

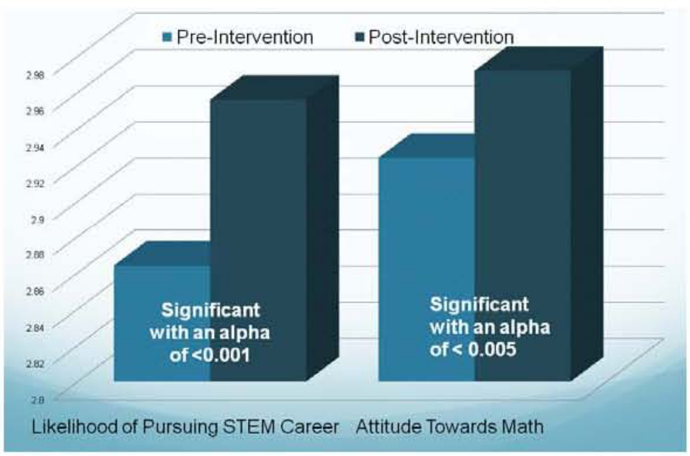

Fig. 3. Academic Year Program

A pre-test Tamhane's analysis showed statistically significant differences between Caucasian and African-American students on the Building and Invention, Science Attitudes, and STEM Career Awareness factors. African-American students consistently reported lower scores for all of these factors. This is interpreted to mean that there are statistically significant pre-existing differences between Caucasian and African-American students in terms of their attitudes toward building and invention, attitude toward science, and their awareness of STEM careers.

The post-test Tamhane's analysis showed statistically significant differences between Caucasian and African-American students only on the Science Attitudes factor, with African-Americans reporting a significantly lower attitude toward science. There were no statistically significant post intervention differences on any other factors between any other races.

The non-equivalent group analysis by gender prior to the intervention showed statistically significant differences on every factor except factor five, Math Attitudes. The non-equivalent group analysis continued to show these differences after intervention. All factors continued to show statistically significant differences between genders except for the Math Attitudes factor.

It may be reasonable to conclude, based on the lack of statistically significant differences found post-intervention between Caucasian and African-American participants, that the intervention played a part in reducing the disparity in attitudes between these demographic groups. However, the intervention was not as successful in reducing the differences between genders.

Summer Academy—The evaluation consisted of a one-group pre-test/post-test study of the students participating in the 2010 Summer Academy made up of students from the Accomack, Fredericksburg, King George, Spotsylvania, and Stafford county public school systems. The population, by race, consisted of 59% Caucasian, 15% African American, 7% Hispanic, 4% Asian, and 15% Other. The data was drawn from a total of 84 students. A total of 16 teachers and 16 S&Es were involved in the program.

A modified form of the Academic Year survey instrument was used in obtaining the data for the 2010 Summer Academy Program. The survey was streamlined, and redundant questions as well as those questions that did not reflect the project's goals, methods and objectives were removed. In addition, questions were added regarding student support and student career decisions to provide information on these important career decision factors.

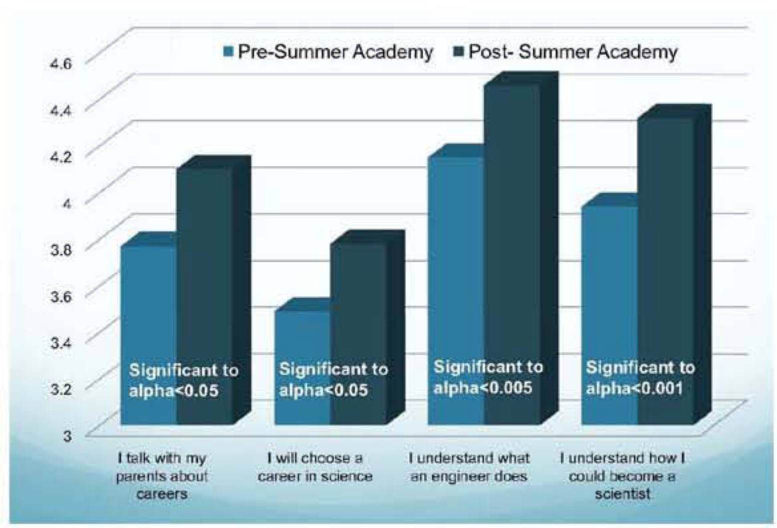

Fig. 4. Summer Academy Program

As discussed above, the data was examined to eliminate spurious information and ensure that data used for the final analysis were accurate and representative of the population. A factor analysis revealed ten factors that are listed in the Appendix along with the range of responses for each factor.

Because of the small size of this survey, results were not separated by race. In addition, because this was a trial period for the modified survey, the factors were not extracted and measurement was accomplished by comparing individual question scores pre- and post-participation in the Summer Academy. A matched-pair t-test was performed on the 74 samples remaining after data cleansing.

As shown in Figure 4, the results indicated that, as a result of the Summer Academy, students were more likely to understand the real-life connections of what they were taught in the classroom. In addition, students were more likely to have talked with their family about careers.

Students reported that they both understood more about what STEM professionals do and the pathways to a STEM career. Finally, students were more likely to report that they would choose a career in science after participation in the Academy. The Appendix contains a complete listing of the questions for which a statistically significant result was obtained along with the pre-test and post-test average Likert responses and the associated levels of significance.

Summary

Information obtained from the study strongly suggests that the students participating in the FY 2009-10 Academic Year and Summer Academy VDP programs:

- exhibit an increased interest in pursuing STEM careers and an understanding of what that involves,
- are more likely to choose a career in science,
- show enhanced attitudes toward mathematics,
- have an increased likelihood of talking to their families about careers,
- have an increased knowledge of what STEM professionals do,
- and have an increased understanding of how they can use the knowledge they acquired in the classroom in real life.

Future Directions

The Holy Grail of assessment is to be able to demonstrate that the results obtained are a result of the elements of the intervention itself and not result of confounding, uncontrolled, and unmeasured "environmental" effects. As a first step toward this goal, a study will be undertaken in which the impact of the mentoring provided by the Navy S&Es on the VDP will be measured. The S&Es are believed to play a vital role in the VDP since they are the source of both the co-teaching and the mentoring elements of the program. Although there is abundant anecdotal evidence of their effectiveness, the authors are aware of no comprehensive study of the effectiveness of STEM professionals who serve in this capacity.

It is also important to know the long-term impact of the results achieved. Do they last long enough, for example, to result in an increased likelihood of enrollment in advanced science and math courses? A preliminary external evaluation of the VDP found that students who participated in the VDP were more likely to enroll in advanced math and science classes at the high-school level. Approximately 25% of students in one particular grade cohort in a school division participated in the VDP during middle school. The high-school courses selected by these students were compared to the courses selected by the remaining students who had not participated in the VDP. The VDP students were more likely to choose advanced math and science courses in both 9th and 10th grade. Further analysis of the data needs to be performed to determine the level of significance of these findings. In addition, a longitudinal study will be conducted to determine the long-term effectiveness of the program by surveying student career choice and college major chosen. The subjects of the study will be current high-school seniors who participated in the VDP when they were in middle school. The survey will be conducted online and will also explore the permanence of changes in the students' attitudes toward STEM and STEM careers.

Appendix A: The Survey Instrument

STEM EDUCATION ALLIANCE / VDP Student Questionnaire

How often have you:

	Never	1-2 times a year	Monthly	Weekly	Daily
Designed and built something					
Programmed a device (for example, a robot or computer)					
Researched world issues					
Participated in science, technology, math, or engineering extracurricular activities (for example, First LEGO® League)					
Worked with a scientist or engineer					

For the activities that you participated in, rate your experience on the following scale:

Did not enjoy *Greatly enjoyed*

1 *2* *3* *4* *5*

_____ Designed and built something

_____ Programmed a device (for example, a robot or computer)

_____ Researched world issues

_____ Participated in science, technology, math, or engineering extracurricular activities (for example, First LEGO® League)

_____ Worked with a scientist or engineer

Are there people in your family who are currently employed in a technical field such as science, engineering, or mathematics? Yes ___ No ____ Don't know _____

Next, please rate how much you agree or disagree with the following statements *by checking the appropriate box to the right of each statement*. (Please check only one box.)

Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
• I like math.					
• I am good at math.					
• I can earn an A in math class.					
• I like helping people with math.					
• I understand how I can use math to solve a problem outside of school.					
• I like science.					
• I am good at science.					
• I can earn an A in science class.					
• I like to look up science-related things on the internet.					
• I understand how I can use science to solve a problem outside of school.					
• I like building things.					
• I often build things in my free time.					
• I am good at building things.					
• I would like to invent something.					
• I understand how I can use building skills to solve a problem outside of school.					
• I like using technology.					
• I enjoy working with computers.					
• I have never used a computer					

• I am good at using technology.					
• I like learning about new gadgets.					
• I understand how I can use technology to solve a problem outside of school.					
• I like solving problems in groups with other students.					
• If given the choice, I would choose to work in a group (rather than alone) to solve a problem.					
• I am good at solving problems in groups with other students.					
• I feel successful when my group works together to solve a problem.					

Next, please rate how much you agree or disagree with the following statements.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
• I am interested in becoming a scientist.					
• I am interested in working in a technical field.					
• I am interested in becoming an engineer.					
• I am interested in working in a math-related career *(like statisticians, accountants, etc.).*					

Now, please rate how much you agree or disagree with the following statements *by circling the appropriate number to the right of each statement—use the following scale:*

STRONGLY DISAGREE			STRONGLY AGREE	
1	**2**	**3**	**4**	**5**

Statement					
• I am confident that I understand basic engineering concepts.	1	2	3	4	5
• I am confident that I understand basic science concepts.	1	2	3	4	5
• I am confident that I understand basic math concepts.	1	2	3	4	5
• If given the proper materials, I am confident that I could design a device to solve a simple problem.	1	2	3	4	5
• I feel supported by peers in pursuing a career in STEM (science, technology, engineering, or mathematics).	1	2	3	4	5
• I feel supported by adults in pursuing a career in STEM (science, technology, engineering, or mathematics).	1	2	3	4	5
• I understand what a scientist, engineer or mathematician does.	1	2	3	4	5
• I understand how I could become a scientist, engineer or mathematician	1	2	3	4	5

---

1. Think about what you would like to do in the future. **How likely are you to choose a career in the field of science, technology, engineering, or mathematics?** C*heck the blank to the left of your choice*:

   ___Very Unlikely ___Unlikely ___Neutral ___Likely ___Very Likely

Appendix B: Factors and Related Questions—Academic Year Assessment

---

FACTOR ONE – BUILDING AND INVENTION

I am good at building things
I often build things in my free time
I would like to invent something
I like building things
I understand how I can use building skills to solve a problem outside of school

Minimum Score 5
Maximum Score 25

FACTOR TWO – INTEREST IN PURSUING STEM CAREER

How likely are you to choose a career in a STEM field?
I am interested in working in a technical field
I am interested in becoming a scientist
I am interested in becoming an engineer
I am interested in working in a math-related career

Minimum Score 5
Maximum Score 25

FACTOR THREE –SCIENCE ATTITUDES

I like science
I am good at science
I can earn an A in science class

Minimum Score 3
Maximum Score 15

FACTOR FOUR –TECHNOLOGY ATTITUDES

I like using technology
I enjoy working with computers
I am good at using technology
I like learning about new gadgets
I understand how I can use technology to solve a problem outside of school

Minimum Score 5
Maximum Score 25

FACTOR FIVE – MATH ATTITUDES

I am good at math
I like math
I can earn an A in math class
I like helping people with math

Minimum Score 4
Maximum Score 20

FACTOR SIX – STEM CAREER AWARENESS

I understand what a scientist, engineer, or mathematician does
I understand how I could become a scientist, engineer or mathematician

Minimum Score 2
Maximum Score 10

Appendix C: Factors and Related Questions—Summary Academy Assessment

---

Highlighted questions loaded on multiple factors.

Factor One

I understand what an engineer does
I understand how I could be an engineer
I understand how I could be a scientist
I understand what a scientist does
I could determine what career would be best for me
I believe I can have almost any career I wish if I put the effort forth
I understand what a mathematician does
I understand how I could be a mathematician
I could choose a career that fits my interests

Factor Two

My family talks with me about my abilities
My family talks with me about my career interests
I talk to my friends about my future
I feel supported by my family
I feel supported by my friends
I plan to learn more about my abilities and interests over time
I have talked about my future with adults outside of my family
I feel supported by adults outside of my family

Factor Three

I understand what a scientist does
I am good at science
I will choose a career in science
I like science
I understand how I could use science to solve a problem outside of school
I am good at solving problems

Factor Four

I enjoy working with computers
I like using technology
I understand how I can use computers to solve a problem outside of school
I believe what I am doing now will help me choose the right career path

Factor Five

I understand what a mathematician does
I understand how I could be a mathematician
I am good at math
I like math
I understand how I could use math to solve a problem outside of school

Factor Six

I plan to talk to lots of people about careers
I plan to spend more time learning about careers
I plan to learn more about my abilities and interests over time
I feel successful when I solve problems

Factor Seven

I like to build things
I understand how I could build something to solve a problem outside of school
I would like to invent something
I have thought about what courses I need to take in school to reach my goals

Factor Eight

I will choose a career in engineering
I will choose a career in math
I believe I can have success with a science, technology, engineering or math career
I believe what I am doing now will help me choose the right career path
I feel supported by my friends

Factor Nine

I like working in groups with other students
I am good at working in groups with other students
I feel successful when my group works together well

Factor Ten

I have talked about my future with adults outside of my family
I feel supported by adults outside of my family

Appendix D: Additional Results from Summer Academy Assessment

---

Questions without a statistically significant change are not included.

Question	Pre-Value out of possible maximum score of 5	Post-Value out of possible Maximum Score of 5	Significance
1. I like to build things.	4.21	4.48	.001
2. I understand how I could build something to solve a problem outside of school.	4.17	4.51	.001
3. I would like to invent something.	4.03	4.30	.001
6. I understand how I could use science to solve a problem outside of school.	4.17	4.44	.005
7. I am good at math.	4.13	4.3	.005
12. I understand how I can use computers to solve a problem outside of school.	4.18	4.49	.005
16. I am good at solving problems.	4.20	4.37	.005
17. I like solving problems.	3.79	4.03	.05
18. I feel successful when I solve problems.	4.23	4.51	.001
19. My family talks with me about my career interests.	3.77	4.1	.02

20. My family talks with me about my abilities.	3.87	4.17	.01
26. I have thought about what courses I need to take in school to reach my goals.	4.25	4.4	.05
27. I could determine what career would be best for me.	4.14	4.32	.03
28. I could choose a career that fits my interests.	4.37	4.51	.04
30. I plan to talk to lots of people about careers.	3.56	3.93	.005
35. I understand what a scientist does.	4.26	4.44	.05
36. I understand what an engineer does.	4.15	4.46	.005
38. I understand how I could be a scientist.	3.94	4.32	.001
39. I understand how I could be an engineer.	3.99	4.28	.04
40. I understand how I could be a mathematician.	3.75	3.95	.05
41. I will choose a career in science.	3.49	3.78	.01