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Program Evaluation • Consultation • Market Research

It's About Discovery
Final Evaluation Report

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

In August 2009, The Ohio State University at Lima (OSU) received a three-year award from the NSF Division of Research on Learning Innovative Technology Experiences for Students and Teachers (ITEST) Program for *It's About Discovery* (IAD). IAD was a partnership between OSU Lima, the University of North Carolina Greensboro, and regional rural schools in Northwest Ohio and North Carolina that equipped teachers to teach new Ford Partnership for Advanced Study (PAS) science curriculum, focused on the theme of *Working Towards Sustainability*. Ford PAS is focused on transforming teaching and learning by preparing students for college and careers with a combination of academic knowledge and 21st century skills. The target audience for the project was 8th to 10th grade students and teachers in rural districts in Ohio and one high poverty rural district in North Carolina.

In March 2010, OSU Lima contracted with Goodman Research Group, Inc. (GRG) to conduct a three-year external summative evaluation of *It's About Discovery*. GRG's evaluation questions were:

1. To what extent does involvement in IAD change participating <u>students'</u>:
   - Knowledge of, attitudes towards, and motivations to pursue STEM-related careers?
   - Related science content knowledge?
   - Knowledge of and attitudes towards STEM workforce skills, including attitudes about ICT?

2. To what extent does involvement in IAD change participating <u>teachers'</u>:
   - Knowledge of STEM content and STEM careers?
   - Knowledge of relevant pedagogy (e.g., inquiry-based methods)?
   - Attitudes towards teaching about STEM careers and ICT?

GRG's core evaluation featured a pre-post design, in which participating teachers facilitated pre- and post-surveys of their students. The first year of evaluation also included pre- and post-surveys of teachers and site visits. Over the three project years, evaluation data were collected from a total of 1,008 students, with 440 pre-post matches.

FINDINGS

- Involvement in IAD had a moderate positive impact on students' knowledge of STEM careers. Students' knowledge about six of 16 careers increased from pre to post, and they learned about how STEM subjects are related to one another and what is required in particular careers.

- Taking part in IAD also had a moderate positive impact on students' interest in pursuing STEM-related careers. Fifty-nine percent to 69% of students indicated the curriculum increased their interest in STEM careers. In one of the three years, there was also a significant increase in the number of specific STEM careers in which students were interested.

- While based on limited evidence, participation in IAD may have a positive impact on students' scientific reasoning skills. In the one year of the evaluation during which students' scientific reasoning was assessed, it increased significantly from fall to spring.

- There was not an association between IAD and students' STEM attitudes. Students' attitudes were relatively positive before IAD and remained so after involvement with the project.

- Involvement in IAD had a positive impact on teachers' knowledge of relevant pedagogy. After their first year with IAD, teachers felt more prepared to teach relevant skills to students. They also were more comfortable integrating non-STEM subjects into their science teaching.

- IAD participation was linked with improvements in teachers' knowledge about STEM careers. Teachers felt more comfortable about supporting students' knowledge of what professionals in a variety of STEM careers do for their work.

- IAD did not impact teachers' overall attitudes about using technology in the classroom. Teachers were relatively positive about using technology in their classrooms from the start of the project.

CONSIDERATIONS

In areas where no impact was measured, it is possible that because participating students and teachers already had positive attitudes, a ceiling effect was created, reducing the chances of any improvement. In addition, the phenomenon of "experience limitation" may be relevant. Students in programs such as IAD often overestimate their knowledge or perceptions about STEM subjects on the pre-tests (Nimon, Zigarmi, and Allen, 2010). Later, because of their experiences during the program, students develop a more realistic perception and hence give lower ratings on the post-test.

During the first year of the program, teachers identified some challenges with program implementation. Specifically, teachers mentioned the timing and the extent to which the curriculum was used in the classroom, the challenging reading level of the student materials, and difficulties related to using technology resources. These challenges may have contributed to no change or minimal attitudinal change.

Lastly, there could have been evaluation measurement issues in the modestly scoped study. Research on other evaluation studies suggests that it is often challenging to assess student interest and to make generalized statements about the effect of STEM education programming (UMass Donahue Institute, 2011).

Research shows that various indicators of student interest and self-confidence in science and math in high school are strongly associated with students continuing with STEM studies through college, above and beyond enrollment and achievement factors (Maltese & Tai, 2011). This was the case in the IAD program in that it helped maintain students' interest in STEM fields. Future iterations of the program may focus on *increasing* the interest and self- confidence of the students in STEM fields. A few recommendations to achieve this goal are:

- Achievement in a certain field helps boost a student's interest and self-concept in that field (Beier & Rittmayer, 2008). The IAD project staff may wish to add an aspect of achievement/competition to the IAD program. Similar programs in the past have used experiences such as Robot building contests to encourage healthy competition.

- Research has shown that out-of-school participation in STEM activities boosts/enhances STEM achievement in school. The IAD staff may wish to support program efforts with an out-of-school component. For instance, there could be an afterschool club and there could be a parent component. Parents or other role models could be encouraged to get involved in helping students cultivate and sustain interest in STEM fields.

  Although reducing the gender gap in attitudes towards STEM was not a specific goal of the IAD project, project staff may wish to consider having future curricular activities address girls' lack of interest in STEM. This is warranted given the contrast between boys' interest and girls' lack of interest.

- Finally, the IAD program staff may wish to consider adding a summer component for students, in addition to the year-long activities. Research indicates that the intensive nature of the summer programs often works to achieve the student outcomes set forth by programs such as IAD (Hayden, Ouyang, Scinski, Olszewsk, & Bielefedt, 2011).

INTRODUCTION

DESCRIPTION OF THE IAD PROJECT

In August 2009, The Ohio State University at Lima (OSU) received a three-year award from the NSF Division of Research on Learning Innovative Technology Experiences for Students and Teachers (ITEST) Program for *It's About Discovery* (IAD). IAD was one of ITEST's *Strategies* projects, interventions meant to motivate K-12 students' pursuit of STEM and ICT career trajectories. The project was a partnership between OSU Lima, the University of North Carolina Greensboro, and regional rural schools in Northwest Ohio and North Carolina that equipped teachers to use new Ford Partnership for Advanced Study (PAS) science curriculum with their students. The strategy also included partnerships with local business and industry, as well as College Access programs, to mentor students.

Ford PAS is an education initiative of the Ford Motor Company Fund. One strand of the initiative is focused on transforming teaching and learning by preparing students for college and careers with a combination of academic knowledge and 21st century skills (i.e., critical thinking, problem-solving, communication, teamwork, creativity, and global awareness), making it particularly responsive to the goals of the ITEST program. The curriculum utilizes case study analysis and role plays, simulations and scientific experiments, research, negotiation, and collaboration.

The Ford PAS curriculum, originally developed by the Education Development Corporation (EDC), is grouped into themes and the IAD project focused on the theme of *Working Towards Sustainability*, which had been newly developed at the time the IAD project was conceived. The modules in the theme engage students in investigating sustainability as an important concept for both people and businesses around the globe. The five *Working Towards Sustainability* modules used by the IAD project are described below:

- *We All Run on Energy* introduces students to energy and its role on Earth and in human life.
- *Energy from the Sun* introduces students to the use of biomass to meet human energy needs.
- *Is Hydrogen a Solution?* introduces the possibilities of a future in which vehicles run on hydrogen-powered fuel cells.
- *The Nuclear Revolution* introduces students to the potential to generate power from radioactive elements found on Earth.
- *Closing the Environmental Loop* introduces the concept of environmental sustainability.

The curriculum was comprised of five four-week modules, designed to be used in various configurations, but about the equivalent of a course if used comprehensively. The participating schools had agreed to offer one *Working Towards Sustainability* module per quarter on a similar timetable to allow for cross-site discussions.

While the IAD project focused on students, it also offered professional development to teachers. Teachers were to participate in at least two workshops offered by EDC, one online workshop on inquiry and information technology and one hands-on workshop on *Working Towards Sustainability*.

The target audience for the project was 8th to 10th grade students and teachers in rural districts in Ohio and one high poverty rural district in North Carolina. The project intended to reach approximately 700 students and 20-25 teachers over two of its three years of funding. One of the motivations for featuring the Ford PAS curriculum in this project was that it had been adopted as a model curriculum in Ohio and there was interest in understanding its impact. Indeed, Bath, Ohio schools and the Douglas Byrd High School in Fayetteville, North Carolina had already been using the Ford PAS curriculum prior to their participation in the IAD project.

DESCRIPTION OF THE EVALUATION

In March 2010, OSU Lima contracted with Goodman Research Group, Inc. (GRG), a research firm specializing in the evaluation of educational programs, materials, and services, to conduct a three-year external summative evaluation of *It's About Discovery*. GRG's evaluation focused on student outcomes – and, to a lesser extent, teacher outcomes – as encapsulated in the following research questions:

3. To what extent does involvement in IAD change participating <u>students'</u>:
    - Knowledge of, attitudes towards, and motivations to pursue STEM-related careers?
    - Related science content knowledge?
    - Knowledge of and attitudes towards STEM workforce skills, including attitudes about ICT?

4. To what extent does involvement in IAD change participating <u>teachers'</u>:
    - Knowledge of STEM content and STEM careers?
    - Knowledge of relevant pedagogy (e.g., inquiry-based methods)?
    - Attitudes towards teaching about STEM careers and ICT?

GRG's core evaluation featured a pre-post design, in which all participating teachers were to facilitate pre- and post-surveys and scientific reasoning assessments of all of their students. The first year of evaluation also included pre- and post-surveys of teachers and site visits. The third year of evaluation was meant to be a more in-depth study of five teachers. In addition to GRG's evaluation activities, the IAD team conducted their own internal evaluation activities throughout the life of the project.

GRG developed and selected teacher and student data collection instruments in collaboration with IAD staff. All of the protocols and their revisions were approved by the Institutional Review Boards of OSU and FSU. See Appendices for copies of all data collections instruments.

GRG submitted annual evaluation reports to the IAD team during the summers of 2010 and 2011. This is the final, end-of-project evaluation report.

METHODS

DATA COLLECTION INSTRUMENTS

Years 1-3 Student Pre-Post Surveys

Students completed a pre-survey at the beginning of the semester in which their teacher implemented the curriculum. (Only one pre-test survey was administered per student.) Students completed a post-survey at the end of each school year (in May 2010, 2011, and 2012). Students completed both pre- and post-surveys online in their schools. GRG provided participating teachers with a survey link and a range of ID numbers to be assigned to their students. Assignment of the ID numbers allowed GRG to match pre- and post- data in order to conduct paired-samples data analyses.

Both the pre- and post-surveys contained closed- and open-ended questions, which addressed the following areas:

- Background and demographic information
- Attitudes towards STEM courses
- Education and career aspirations and plans
- Interest in and knowledge of science careers
- Perceptions of their scientific and work-force skills
- Program-related information (*post-surveys only*)

Year 1 Student Scientific Reasoning Assessment

During Year 1, students' scientific reasoning skills were assessed using the Critical Thinking Readings in Nonfiction for High School Students (Barnes, Schroeder, & Burgdof, 2002). At pre and post time points, the assessment consisted of three non-fiction stories with two open-ended questions about each story. GRG provided teachers with a scoring instruction sheet (including a rubric; see Table 1) for grading students' answers.

Table 1
Rubric for Grading Scientific Reasoning Assessment

Score	Description of Score
4	See "3," plus added insight; good use of vocabulary; sophistication demonstrating higher understanding of topic.
3	Responds clearly and fully to question and to display; well organized.
2	Responds to prompt; partially responds to content; shows opinion but not reasoning; writing hinders understanding.
1	Partial response to prompt; partially alludes to the question, but does not answer specifically; difficult to comprehend.
0	Off prompt; does not respond to question; incoherent.

Year 1 Teacher Surveys and Site Visits

Ten teachers completed a pre-survey before their summer 2009 Ford PAS training and eight teachers completed the post-survey online at the end of the 2010 school year. The teacher surveys focused on teachers' knowledge about STEM careers and their attitudes about teaching STEM and ICT.

During that same academic year, GRG conducted observations in six classrooms in schools in northwest Ohio. Through structured observations, interviews with the teachers, and focus groups with the students, GRG researchers were able to experience/view how the project was being implemented.

SAMPLE PROFILE

Over the three project years, evaluation data were collected from a total of 1,008 students. The pre-post sample sizes for each year were different because not all students participating in each year took both surveys (See Table 2). For the pre-post analyses of the data, paired sample t-tests were used only on those who completed both pre- and post- tests. Consequently, pre-post data for comparative analyses had a smaller N.

In addition to those students who participated in Ford PAS during one academic year, 66 students participated in the program during both Years 1 and 2, and 27 students participated in the program during both Years 2 and 3. No student participated in the program all three years. For every student, only one pre-test was administered.

Table 2
Evaluation Data Student Sample Sizes Across Three Years

	Baseline survey	Post-survey	Both surveys, allowing for pre-post analyses
2009-2010 cohort	N = 266	N = 157	N = 118
2010-2011 cohort	N = 422	N = 362	N = 270
2011- 2012 cohort	N = 127	N = 91	N = 52

Student Demographics

Student demographic data were obtained on the student pre-program surveys. Each of the three years, there were equal or close to equal percentages of boys and girls (See Table 3). The percentages of 9th graders were higher in Years 1 and 3 than in Year 2. Although the total number of participants decreased each year, the percentage of non-White participants in the study increased each year, probably a reflection of the teachers/schools that continued to participate.

Table 3
Profile of Student Respondents[1]

		Year 1	Year 2	Year 3
Gender	Females	50%	54%	54%
	Males	50%	46%	46%
Grade level	9th Grade	81%	59%	84%
	10th Grade	19%	40%	16%
Racial/ethnic background	White	91%	89%	75%
	Black or African American	9%	7%	12%
	Spanish/Hispanic or Latino	4%	6%	3%
	Asian	3%	<1%	2%
	American Indian or Alaskan Native	3%	5%	9%
	Native Hawaiian or Other Pacific Islander	–	<1%	>1%
	Other	2%	3%	2%

N varies from 112-118 (Year 1); 362 to 422 (Year 2); 125 to 136 (Year 3)
Percentages for racial/ethnic background may not add to 100% because of rounding and multiple responses.

Students' Baseline Computer Usage

At baseline, 91% of students across all three years (n=743) reported using a computer at home, with 71% using it for at least one hour per day. Eighty-two percent of participants used their home computer to do research for school and 73% used it to type homework assignments.

The percentage of IAD participants with access to the Internet at home exceeded that of the national average. According to the 2009 U.S. Census Bureau[2], 77% of people between the ages of 3 and 17 live in a household with Internet access. In contrast, among the IAD student sample, 96% (n=698) of the 727 students who reported on Internet usage indicated having access to it at home. This percentage is also greater than typical mid-Western homes, in which 74% of families have such access.

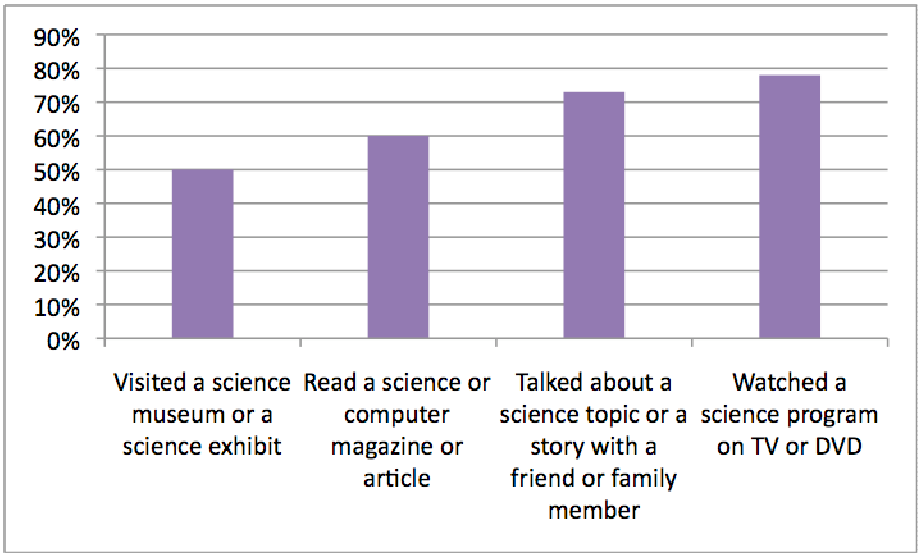
This familiarity with computers and extensive access to the Internet may explain some of the outcomes in the study as indicated later in the report. It could explain, in some part, the high ratings on the attitudes toward technology found on the baseline surveys.

[1] Data were generated from answers provided by the students on the pre-surveys
[2] Available at http://www.census.gov/hhes/computer/publications/2009.html

Students' Participation in Science Activities

At baseline, students had participated in science-based activities such as reading scientific articles, visiting science museums, and watching science programs (See Figure 1). Once again, these positive findings could explain, to some extent, the higher ratings of the students' own STEM attitudes on the baseline surveys.

Figure 1
Percentage of Students who Participated in Science Activities Before IAD



N=810

FINDINGS

This section focuses primarily on the findings related to students' experiences and learning because we have three years of student data. A summary of the teacher data collected by GRG during year one is presented at the end of this section.

The three-year findings from the project are organized based on the following topics:

- Appeal of the Ford PAS Program for the students
- Students' knowledge of STEM careers
- Students' interest in STEM careers
- Students' scientific reasoning skills
- Students' STEM attitudes, science competency, and workforce skills
- Teachers' experiences

FORD PAS MODULES WERE MODERATELY INTERESTING TO STUDENTS.

Within the whole student sample, on average, each activity was rated by the students as *somewhat* interesting. *The Nuclear Revolution* received the highest mean rating for interest level. In addition, gender differences were found in the ratings for this particular activity (t = 2.25; $p < .05$), with male students giving it significantly higher mean ratings (3.4) than female students (3.03).

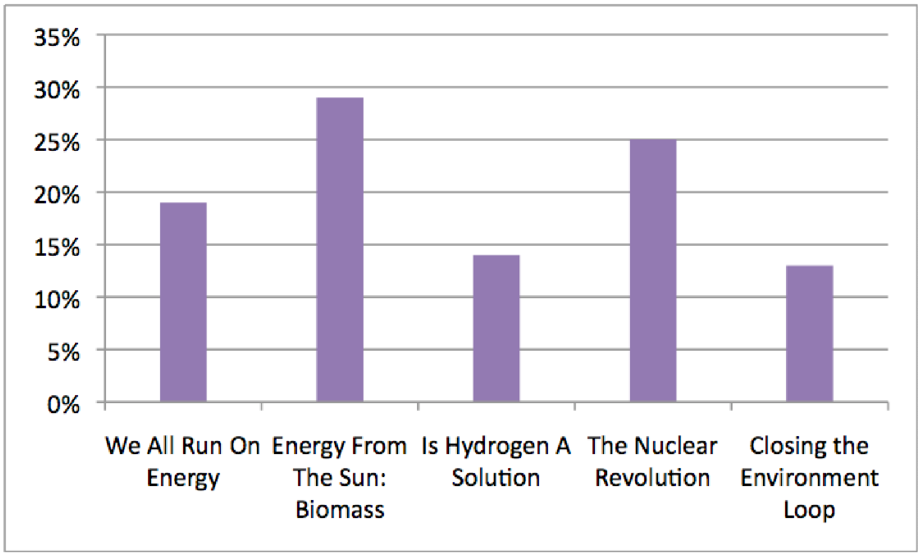
Table 4
Student Ratings of Program Modules

Activity (3-year mean rating on 1-5 scale)		Not at all OR A little Interesting	Somewhat Interesting	Very OR Extremely Interesting
We All Run On Energy (3.05)	Year 1	21%	50%	27%
	Year 2	29%	43%	28%
	Year 3	27%	51%	21%
Energy From The Sun: Biomass (3.05)	Year 1	29%	47%	23%
	Year 2	30%	44%	26%
	Year 3	36%	28%	35%
Is Hydrogen A Solution (2.96)	Year 1	31%	41%	26%
	Year 2	32%	41%	24%
	Year 3	39%	40%	21%
The Nuclear Revolution (3.10)	Year 1	24%	38%	38%
	Year 2	30%	38%	32%
	Year 3	41%	24%	33%
Closing the Environment Loop (3.01)	Year 1	31%	45%	23%
	Year 2	34%	43%	23%
	Year 3	38%	29%	32%

N: year 1 = 109; year = 267; year 3= 91

The two modules titled *Energy from the Sun* and *The Nuclear Revolution* were the most popular of the five modules. A higher percentage of students chose them as their most favorite activity. On the other hand, the least number of students chose *Closing the Environmental Loop* as their favorite activity (See Figure 2).

Figure 2
Student's Choice of Favorite Activities



* Percentages are calculated based on total participants for each year

Module use likely differed by teacher; while some teachers may have used all the modules, others may have used only a subset. Tables 5 and 6 indicate the exposure of the students to the varying number of modules.

Table 5
Student Participation in the FORD PAS Modules

	Year 1	Year 2	Year 3	Total
We All Run On Energy	41%	39%	49%	43%
Energy From The Sun: Biomass	40%	42%	49%	44%
Is Hydrogen A Solution	42%	40%	47%	43%
The Nuclear Revolution	44%	41%	48%	44%
Closing the Environment Loop	34%	35%	46%	38%

* Percentages are calculated based on total participants for each year. Appeal data are missing for students who only took the pre-test.

Table 6
Students' Extent of Participation

Total # of modules	% of participants
1	3%
2	3%
3	3%
4	3%
5	23%

* Percentages are calculated based on total participants for each year. Data missing for students who only took the pre-test (65%)
** Total N across three years = 1008

Students also provided reasons for selecting a particular module as their most favorite (See Table 7). Of the students who chose to answer this question, a majority (78%) seemed satisfied with the content (an interesting or relevant topic) or the format (hands-on or exploratory learning). Opportunities to work with their team members and the ease of an activity seemed to be least important when choosing their favorite activity.

Table 7
Students' Reasons for Enjoying Their Favorite Ford PAS Module across the Three Years

Reason	% of Students
Because topic was interesting/relevant	36%
Because of the hands-on nature of the activity	21%
Because it involved exploratory learning (scientific explanations)	21%
Because it was fun	11%
Because it was the only activity we did	5%
Because it was easy to understand	4%
Because it involved collaboration or working in teams	3%
Other	4%

N = 287
Note: Total exceeds 100%, as some responses were coded in multiple categories.

Following are some direct quotes from the students about their favorite activities:

We All Run on Energy

- *"We had the chance to experience all types of energy between wind turbines, water wheel, and solar cells."*
- *"It is interesting to know all the types of energy we encounter and run on throughout the day."*

Energy From the Sun: Biomass

- *"This activity was my favorite because we got to make homemade stoves and that was really cool."*
- *"It is interesting to see where our energy comes from."*
- *"We got to be outside in the sun recording temperatures of water before and after sun exposure. This helped me learn about how much energy really does come from the sun."*
- *"This was my favorite because we got to learn about stoves used for biomass and how many different ones there are, and what they run on instead of coal or wood."*

Is Hydrogen a Solution

- *"I like the idea of trying to create a new way to run vehicles and lessen the amount of fossil fuels consumed."*
- *"This activity was my favorite because we got to look through the microscopes and see the different cells in the organisms."*
- *"We got to build things. Also, we got to see how much and how far they would run."*

The Nuclear Revolution

- *"This activity was my favorite because we had the chance to learn about what goes on in a power plant. I think that our generation learns more about things such as this when we go out and explore."*
- *"It was my favorite because we got to take care of plants and watch them grow every day. I also liked the fact that it was kind of hands on, like how we got to plant the flowers and put all of the soil into the little boxes."*
- *"Made me feel globally connected to the world and its energy struggle."*

Closing the Environment Loop

- *"I liked learning about new ways to make products we use environmentally friendly."*
- *"This was very fun because we worked in groups and read about developing countries and learned how to make things more sustainable."*
- *"We were able to use our critical thinking to come up with our own designs."*
- *"Because we got to be more "hands-on" with what we were doing."*

FORD PAS MODERATELY INCREASED STUDENT KNOWLEDGE OF STEM CAREERS.

Multiple student measures assessed pre-post changes in their knowledge of STEM careers. These included:

1. Students' post-program ratings of program effectiveness in increasing their STEM career knowledge;
2. Students' pre-post ratings of knowledge about specific STEM careers; and
3. Students' post-program open-ended responses about what they learned through the program.

Program Effectiveness in Increasing STEM Career Knowledge

On the post-survey, students indicated the extent to which the Ford PAS lessons and activities increased their knowledge about careers in STEM fields. Students indicated that these activities increased their knowledge about STEM careers from *a little* to *some extent* (See Table 8). The average Year 1 rating (2.69) was significantly lower than Years 2 ($t = 2.507$, $p < .05$) and 3 ($t = 3.325$, $p < .01$), suggesting that the program had a slightly stronger finish in terms of its perceived effectiveness in increasing students' knowledge about STEM careers.

"When you have a career in science, you always have to be skeptical about ideas until they are proven and that we always have to be able to test ideas."

"The most important thing I learned about careers in science is that it is extremely important to be exact and precise."

"I learned that to be a marine biologist, I have to know some math and technology."

- IAD students about what they learned from the program

Table 8
Student Ratings of Extent to Which the Program Increased Their Knowledge of STEM Careers

Year	Mean (1-5)	Not At All or A little	Some	Quite A Bit or A Great Deal
Year 1	2.69	42%	31%	26%
Year 2	2.90	30%	46%	24%
Year 3	3.08	29%	36%	35%
Total	2.93	30%	41	28%

N: Year 1 = 109; Year 2 = 267; Year 3 = 91

Each year, male students gave higher ratings than did female students (See Table 9), and this gender difference was statistically significant during the last year of the project (t = -2.42, $p < .05$). The average rating of male students (3.36) corresponded to a view that the program increased their knowledge *some* to *quite a bit*, whereas the average ratings of female students (2.79) meant they found the program increased their knowledge *a little* to *some*.

Table 9
Gender Differences in Extent to Which the Program Increased Knowledge of STEM Careers

	Males (mean score)	Females (mean score)
Year 1	2.91	2.78
Year 2	2.92	2.80
Year 3*	3.36	2.79
Total	2.79	3.0

*$p < .05$

Knowledge about Specific STEM Careers

As a second measure of changes in knowledge of STEM careers, we provided on both pre- and post- student surveys a list of 16 STEM careers. Students rated their knowledge of each career on a 3-point scale in which *1* indicated *I have no idea what these professionals do for their work*, *2* indicated *I can guess what these professionals do for their work*, and *3* indicated *I know what these professionals do for their work*. Table 10 shows the percentage of students whose chose the third category for each career, pre- and post-program.

Table 10
Overall Pre-Post Percentages of Students with Knowledge of Specific STEM Careers (giving rating of "I know what this professional does for his/her work")

Career	% of students indicating existing knowledge on the pre-test	% of students indicating knowledge on the post-test
Inventor*	82%	74%
Mathematician*	76%	72%
Biologist*	71%	70%
Chemist	65%	64%
Archaeologist	63%	61%
Nutritionist	56%	58%
Geologist*	53%	54%
Engineer	53%	56%
Technologist	48%	54%
Physiologist	45%	46%
Neurologist*	33%	40%
Conservationist*	29%	41%
Ecologist	28%	34%
Hydrologist*	17%	31%
Toxicologist*	13%	27%
Otolaryngologist*	5%	13%

N = 329
*$p < .05$

As Table 10 indicates, overall the percentages of students who indicated they had prior knowledge about these careers ranged widely. A large majority of students indicated that they knew about careers such as inventor (82%), mathematician (76%), and biologist (71%) on the pre-survey. However, these are the same careers for which we found statistically significant decreases in knowledge from pre- to post-program. A probably explanation for this decrease is that the program actually made the students aware of how much they didn't know about the careers and led them to have a more realistic perception of their own knowledge about these careers after the program, a phenomenon sometimes referred to as "experience limitation" (Nimon, Zigarmi, and Allen, 2010).

Students' ratings also indicated a statistically significant increase in their knowledge of about six of the 16 careers on the list: Geologist, Neurologist, Conservationist, Hydrologist, Toxicologist, and Otolaryngologist. Students had minimal baseline knowledge about three of these six careers; before Ford PAS only one or two in ten students knew what Otolaryngologists, Toxicologists, and Hydrologists did for their work. Increase in career knowledge was not related to the total number of modules in which the student participated.

What Students Learned Through the Program

In addition to ratings, the students also indicated, in their own words, the most important thing they had learned during the school year about careers in science, engineering, math, and technology. Across the three years, the open-ended responses of the students who answered the question (N=300) yielded a range in categories, from learning about how STEM subjects are related to one another to what is required in a particular career to what is involved in the scientific process. These categories are displayed in Table 11. Overall, students seemed to remember various things learned about STEM subjects and careers, from connections among STEM subjects to work and science skills required in those careers.

Table 11
Student Responses about the Most Important Thing Learned

Category	Explanation of categories
Interconnections among STEM subjects (26%)	Students learned that many STEM fields overlap and many jobs will involve some form of STEM work.
Job requirements (25%)	Students mentioned different requirements for acquiring 21st century careers (i.e. STEM courses, a college degree etc.).
Scientific process (21%)	Students highlighted skills that are necessary for becoming a good scientist, such as, keeping good records, being exact or precise, running statistical analyses and conducting experiments.
Work skills/ethic (13%)	Students mentioned skills or ethics that are important in any career, such as paying attention, staying focused, overcoming adversity, communicating accurately, and remaining determined.
Specific STEM field (6%)	Student comments in this category were single words identifying a STEM field.
Unsure (12%)	Comments in this category were from students who were unsure or could not recall what they learned about STEM careers.
Miscellaneous (8%)	Comments in this category were extremely vague and could not be coded into a category. For "all of the above", "everything" and "some stuff".

STUDENT INTEREST IN STEM CAREERS REMAINED STABLE FROM PRE TO POST CURRICULUM.

Multiple ratings from students assessed changes in their consideration of specific STEM careers. These included:

1. Students' post-program ratings of program effectiveness in increasing their interest in STEM careers;
2. Students' pre-post ratings of their interest in specific STEM careers; and
3. Students' pre-post responses about their anticipated future jobs.

Program Effectiveness in Increasing Student Interest in STEM Careers

On the post-survey, students indicated the extent to which the Ford PAS lessons and activities increased their interest in pursuing careers in STEM fields. Fifty-nine percent to 69% of students indicated that these activities increased their interest in STEM careers *some, quite a bit, or a great deal* (See Table 12).

"It is a cooperative experience and shows just how easy it really is to perform an experiment or conduct research when working together. This helped divide the work and discuss results."

- An IAD student's reaction to the teamwork aspect of the program

Table 12
Student Ratings of Extent to Which the Program Increased Interest in STEM Careers

Year	Mean (1-5)	Not At All OR A little	Some	Quite A Bit OR A Great Deal
Year 1	3.03	32%	33%	36%
Year 2	2.6	42%	40%	19%
Year 3	2.75	38%	32%	29%

N: Year 1 = 112; Year = 267; Year 3= 90

Gender differences were found in these ratings only during the last year of the project (t = -2.07, $p < .5$). Male students had a higher mean rating (3.02) than did female students (2.46) on the extent to which the program increased their interest in pursuing STEM careers. In practical terms, this translates into boys experiencing *some* and girls experiencing *a little* to *some* increase in interest.

Interest in Specific STEM Careers

On both pre- and post-surveys, we provided students with the same list of 16 STEM careers mentioned earlier (See Table 13) and asked them to indicate which jobs they were interested in doing when they grew up. Each career was scored 0 (not interested) or 1 (interested) and a cumulative score was calculated to indicate students' interest in careers in STEM on pre- and post-surveys. The possible range of scores was 0 to 16.

Students' scores showed a statistically significant increase from pre to post only during Year 2, at which time the number of careers they were interested in increased from 4.7 on the pre-test to 9.1 on the post-test ($p < .05$). This difference was not found during Years 1 and 3. Of note, during Year 3, male students indicated significantly greater interest in STEM careers on the post-survey than did female students. This difference was not found on the pre-survey (See Table 13).

Table 13
Gender Differences in Interest in STEM Careers

		Males (mean score)	Females (mean score)
Year 3	Pre-test	1.8	2.0
	Post-test*	2.6	1.4

* $p < .01$

Students' Pre-post Responses about their Anticipated Future Jobs

On both pre- and post-surveys, students listed the one job they would most like to have when they are 30 years old. The responses of the students were coded in terms of whether or not they represented a STEM field. As Table 14 indicates, students' interest in a STEM career remained consistent, rather than increasing. Within the STEM fields, a majority of the students were interested in health sciences and medical careers. Among these, the most popular careers were nursing, veterinary sciences, and physical therapy.

These data are consistent with those obtained through the alumni survey of Ford PAS graduating class of 2009. Fifty-four percent of these Ford PAS alumni were thinking of a career in STEM.[3]

Table 14
Students' Desired Jobs at 30 Years Old Coded by STEM Fields

	% of students on baseline survey	% of students on post-survey
STEM	53%	54%
Health Sciences/Medicine	28%	28%
Technology	7%	9%
Science	7%	9%
Engineering	9%	8%
Mathematics	2%	1%
Non-STEM	45%	40%
Other[4]	2%	6%

N=173

The word cloud below, in which the size of the word signals its relative frequency among student responses, illustrates the post-test responses of the students to the question of which job a student most desired to have by age 30. Similar to the finding in Table 14, the word cloud also demonstrates that nursing was a popular career for this group of students. The STEM career of "engineer" features prominently among the responses.

[3] http://fordpas.org/alumni-survey
[4] Other category included responses like "I don't know", "Undecided", and "I am not sure".

Figure 3
Word Cloud of Student Choice of Future Jobs: ***What is the one job you want to have the most when you are 30 years old?***

Scientific Reasoning Skills

During the first year of the IAD project, 102 students completed both pre- and post-quizzes. Students' scientific reasoning scores significantly increased from fall to spring (p<.001). On average, students scored .342 points higher on the post-quiz. Female students had significantly higher scores than did male students for both the pre- and the post-quiz. The change in pre- to post-quiz scores was similar for both groups.

Further analysis (ANOVA) revealed that variation in the increase of scores resulted from classroom differences: students from certain classrooms had significantly different ratings from students in other classrooms (F (95) = 6.291; p<.01). During the site visits, some teachers explained they had struggling readers, while other teachers said they had advanced readers. Since reading comprehension was a critical part of the assessment, this may have affected certain students' scientific reasoning scores.

STUDENTS' STEM ATTITUDES, SCIENCE COMPETENCY, AND WORK FORCE SKILLS REMAINED STABLE FROM PRE TO POST CURRICULUM.

Across the three year, a third of the students communicated or worked together with other classes in their school or other schools on developing or sharing the PAS projects. Students used words like 'fun', 'cool', and 'interesting' to describe this experience.

Four scales were developed to assess students' attitudes towards science, engineering, technology, and math. Additional scales assessed students' academic self-competence in STEM and students' comfort with traditional science skills and workforce skills. Composite scores created for each scale were used in the analysis of students' STEM attitudes and perceived competence. The reliability of these scales was established by GRG during Year 1.

Data for all three years combined indicate that students' attitudes toward STEM subjects as well as their perceived competency in STEM subjects and workforce skills remained fairly stable from pre- to post-test (See Table 15). Most of the mean scores were between the 60th and 80th percentiles of the possible range of scores both before and after exposure to the curriculum.

Table 15
Three-year Mean Pre and Post Scores on Evaluation Scales

	Alpha scores for reliability	Mean pre-test score (%ile)	Mean post-test score (%ile)	Possible range of scores
Attitude towards science	.843	72.2 (74)	70.2 (71)	14 - 98
Attitude towards engineering	.819	26.5 (64)	25.7 (62)	6 - 42
Attitude towards technology	.884	88.7 (80)	83 (74)	16 - 112
Attitude towards math	.788	27.2 (77)	25.1 (71)	5 - 35
Self-competence in STEM	.823	51.4 (66)	49 (64)	11 - 77
Traditional science skills and workforce skills	.888	76.7 (48)	75.8 (47)	23 – 161

N=253–314

Further analyses indicated that male students had higher ratings than did female students on four of the above scales on the pre-surveys, namely, attitude towards science, attitude towards engineering, self-competence in STEM, and traditional science skills and workforce skills. These gender differences persisted on the post-surveys (See Table 16).

Table 16
Gender Differences on Attitudinal and Skills Scales

	Mean pre-test scores		Mean post-test scores	
	Males	Females	Males	Females
Attitude towards science*	74.2	69.8	70.3	67.3
Attitude towards engineering*	29.4	23.1	28.1	22.1
Attitude towards technology	89.3	86.6	84.2	82.7
Attitude towards math	27.3	26.9	24.9	23.8
Self-competence in STEM*	53.2	48.8	50.9	46.9
Traditional science skills and workforce skills*	79.5	73.4	76.2	72.3

*$p < .05$

DURATION OF INTERVENTION WAS NOT ASSOCIATED WITH POSITIVE RESULTS.

The data collection included 66 students who had participated in the program during both Years 1 and 2, and 27 students who had participated in the program during both Years 2 and 3. (The data collection did not include any students who had participated in the program across all three years.) We explored trends in student outcomes over time, with the hypothesis that outcomes would improve over time with added exposure to the curriculum.

The statistically significant differences found in the trend analysis are reported in Table 17. All of these significant differences were in the negative direction, that is, lower ratings existed on the post-tests than on the pre-tests. No gender differences were found in this trend analysis.

Table 17
Trend Data Analyses Over Three Years

Finding	Year 1 Mean ratings		Year 2 Mean ratings		Year 3 Mean ratings	
	Yr 1 Pre	Yr 1 Post	Yr 2 Pre	Yr 2 Post	Yr 3 Pre	Yr 3 Post
Interest in STEM careers decreased from Year 1 pre to Year 2 post	5.1			2.0		
Interest in STEM careers decreased from Year 1 post to Year 2 post		3.8		2.0		
Comfort in traditional science and workforce skills increased from Year 1 post to Year 2 post		67.3		76.5		
Math attitudes decreased from Year 2 pre to Year 3 post			27.5			23.7
Self-competence decreased from Year 2 post to Year 3 post				88.8		75.7

IAD PROFESSIONAL DEVELOPMENT HELPED TEACHERS PREPARE TO TEACH STEM AND 21ST CENTURY SKILLS.

As stated earlier, one of the goals of the project was to provide professional development for 15 teachers on inquiry-based education, the Ford PAS module *Working Towards Sustainability*, and other Ford PAS opportunities. Early in the evaluation, GRG examined the extent to which participation in IAD improved teachers' STEM content knowledge and knowledge of STEM careers, their pedagogical content knowledge (e.g., inquiry-based methods), and their attitudes towards teaching about STEM careers and ICT.

IAD's impact reached beyond teachers' increased comfort teaching many STEM skills; teachers reported increased comfort teaching critical thinking, 21st century skills, and interdisciplinary connections as well. The most definitive and dramatic results were changes in teachers' attitudes toward teaching students about a wide array of STEM careers.

Teaching STEM and 21st Century Skills

In order to assess changes in teachers' comfort with STEM and 21st century skills we asked them to respond to the same question on pre- and post-surveys: *"How prepared do you feel to teach the following skills to your students?"* Teachers responded to each item on the following five-point Likert scale: (a) not at all prepared, (b) a little prepared, (c) somewhat prepared, (d) very prepared, and (e) extremely prepared.

The 21 STEM and 21st century skills we assessed are shown in Table 18. For the eight teachers who completed pre- and post-surveys, the Table shows their mean pre-survey score, their mean post-survey score, and the mean difference between the two scores (the "change score"). As indicated by the change scores, teachers' mean preparedness ratings for all but two of the 21 skills increased after one year of participating in IAD. In three cases, the changes were both statistically and practically meaningful. Before IAD, teachers were only somewhat prepared to teach their students to present multimedia projects, to leverage the strength of others to accomplish a common goal, and to link science content to their own lives. After IAD, teachers felt very prepared in each of these areas.

Given the prominence of the online cross-classroom collaboration as an element within the IAD program, the significant increase in teachers' preparedness to teach their students to present multimedia projects to other classrooms or schools is almost certainly a result of their experience with the program. While teachers initially struggled to set up the videoconferencing software, they eventually gained competence with the technology. "*Once we (the teachers) got some practice in facilitating the activity, the students did benefit and saw the power of the technology*," one teacher reported.

In the two cases where the mean scores did not increase – collecting data and developing and identifying questions to clarify various points of view – they remained the same. Both before and after IAD, teachers felt very prepared to teach their students the skill of data collection and somewhat to very prepared to teach them how to formulate clarification questions. Thus, after IAD, there remained some room for increased preparedness in helping students develop questions. There also remained room for improvement with regard to role-playing real world situations.

Table 18
Teachers' Mean Preparedness to Teach Skills, Before and After IAD

	Pre	Post	Change
Presenting multimedia projects to other classrooms or schools	3.38	4.13	0.75*
Leveraging strengths of others to accomplish a common goal	3.38	4.13	0.75*
Linking science content to their own lives	3.38	4.00	0.63*
Recording observations	4.00	4.38	0.38
Drawing conclusions from data	4.00	4.38	0.38
Using evidence to create, test, and determine the best way to solve a problem	4.00	4.38	0.38
Using communication for a range of purposes (e.g., to inform, instruct, motivate, and persuade)	3.75	4.13	0.38
Role-playing real world situations	3.13	3.50	0.38
Understanding, negotiating, and balancing diverse views and beliefs to reach workable solutions	3.25	3.63	0.38
Making predictions about data	4.00	4.25	0.25
Managing goals and time within a long-term project	3.38	3.63	0.25
Respecting cultural differences and working effectively with people from a range of backgrounds	3.75	4.00	0.25
Connecting projects in the science classroom to the larger world	3.50	3.75	0.25
Presenting data using tables, graphs, or charts	4.25	4.38	0.13
Following proper laboratory safety procedures	4.13	4.25	0.13
Identifying the steps needed to solve a problem	4.25	4.38	0.13
Finding and evaluating information in Internet searches	3.63	3.75	0.13
Critically reading and understanding scientific texts	3.75	3.88	0.13
Analyzing and interpreting media messages	3.63	3.75	0.13
Collecting data	4.25	4.25	0.00
Developing and identifying questions to clarify various points of view	3.50	3.50	0.00

N=8
* $p<.05$

Using Technology in the Classroom

To measure changes in teachers' attitudes about using technology in the classroom, we presented them with a list of relevant statements on pre- and post-surveys and asked their level of agreement with each. They responded on a five-point scale: (a) strongly disagree, (b) disagree, (c) undecided or neutral, (d) agree, and (e) strongly disagree. The results are presented in Table 19 for the eight teachers who completed pre- and post-surveys. For those statements with a negative valence (shaded in gray), the desired direction of the change score was negative (i.e., teachers disagree more with such statements).

Teachers' mean attitude ratings changed in the desired direction for six of the 15 statements, remained the same for two, and changed in the unexpected direction for the other seven statements. However, teachers were relatively positive about using technology in their classrooms from the start of the project, and none of the changes we measured were either statistically or practically meaningful, with one exception: After their first year with IAD, teachers felt more prepared to help their students use technology to learn. Also, of note, is that teachers were undecided or neutral as to whether their schools had the resources (e.g. laptops, computer lab access, internet reliability) they needed to use technology successfully with their students. This was important context for the IAD team in the first year of their project.

Also important were the suggestions teachers offered as to how the IAD team could support their use of technology during the project. Almost all teachers said that limits on classroom time constrained their ability to bring new technology into the classroom. For example, they would have liked more opportunities to learn how to use the videoconferencing technology *before* using it in the classroom, so that they would not have to spend class time working it out.

Table 19
Teachers' Mean Technology Attitudes, Before and After IAD

	Pre	Post	Change
I feel prepared to help my students use technology to learn.	3.75	4.25	0.50
I am usually the first teacher at my school to try out new technology to teach my students.	3.75	4.25	0.50
I know professional persons I can contact if I have questions about technology or need help with a technology-related issue.	3.63	4.13	0.50
Using new technology intimidates me.	2.13	1.63	-0.50
I enjoy using technology to learn and communicate.	4.13	4.38	0.25
Students' use of technology enhances their science learning.	4.13	4.25	0.13
Working with new technology makes me feel tense and uncomfortable.	2.00	2.00	0.00
Working with technology is enjoyable and stimulating for my students.	4.00	4.00	0.00
My school has the resources I need to use technology successfully with my students.	3.13	3.00	-0.13
The amount students learn from using technology is not worth the time and expense of doing such activities.	1.63	1.88	0.25
The challenge of learning new technology is exciting to me.	4.25	4.00	-0.25
Overall, I am comfortable using technology for my professional needs, including teaching.	4.38	4.13	-0.25
I am confident about learning to use new technologies.	4.50	4.25	-0.25
Using technology is very frustrating for students.	2.25	2.63	0.38
I am excited about supporting my students' learning by using new technology both in and out of the classroom.	4.38	4.00	-0.38

Making Interdisciplinary Connections in the Science Classroom

One of the goals of IAD was to increase teachers' comfort with making interdisciplinary connections in their classrooms. The training and curricular modules encourage teachers to incorporate Language Arts, Math, Economics, World Culture/History, and Government/Civics into their science teaching. We asked teachers before and after their first year in IAD whether they were integrating these subjects into their teaching and then to rate their comfort with integrating each subject into their science teaching. Teachers responded using a five-point scale: (a) not at all comfortable, (b) a little comfortable, (c) somewhat comfortable, (d) very comfortable, and (e) extremely comfortable. Table 20 shows these results.

In the fall of 2009, with the exception of math, fewer than half of participating teachers were incorporating these subjects into their science teaching. Notably, at the end of the school year, the number of teachers making these interdisciplinary connections increased for every one of these subjects. Moreover, teachers' comfort integrating Economics and World Culture/History into their science teaching increased significantly. In these two areas, teachers were a little to somewhat comfortable initially and were somewhat to very comfortable after their first year in IAD.

Table 20
Teachers' Integration of Non-STEM Subjects in the STEM Classroom

	Integrate into Science?		**Comfort Integrating into Science Teaching**	
	Number of Teachers Summer 2009	**Number of Teachers Spring 2010**	**Mean Rating: Summer 2009**	**Mean Rating: Spring 2010**
Language Arts	4	7	3.00	3.43
Math	7	8	4.13	4.00
Economics	2	4	2.71	3.57*
World Culture/History	4	6	2.71	3.43**
Government/Civics	3	5	2.57	3.29

N=7-8
*p<.05, ** p<.01

Teaching about STEM Careers

We evaluated teachers' comfort with teaching about STEM careers by presenting them with a list of science careers that they and their students were to learn about in the Ford PAS curriculum and asking them: *"Please indicate how comfortable you currently feel about supporting students' knowledge of what professionals in these careers do for their work."* They responded on the same five-point comfort scale described above.

The STEM careers we assessed are shown in Table 21. Teachers' mean comfort ratings for each of them increased between summer 2009 and spring 2010. The changes were statistically significant in eight cases. In the cases of Water Quality Engineer, Marine Geologist, Aquatic Ecologist, DNA Technologist, and Health Toxicologist, teachers were initially somewhat comfortable supporting students' knowledge, but were very comfortable after IAD. In the cases of Biopacking Engineer, Hydrologist, and Hydropower Engineer teachers were only a little comfortable prior to IAD, and were somewhat comfortable afterward. These three careers are among several that, despite increases in comfort, teachers still had room to grow as they continued receiving professional development through IAD.

Table 21
Teachers' Mean Comfort to Teach STEM Careers, Before and After IAD

	Pre	Post	Change
Water Quality Engineer	3.00	4.13	1.13*
Biopacking Engineer	1.50	2.63	1.13**
Hydrologist	2.14	3.14	1.00*
Hydropower Engineer	2.13	3.13	1.00*
Marine Geologist	2.50	3.50	1.00*
Otolaryngologist	2.00	3.00	1.00
Aquatic Ecologist	2.63	3.50	0.88*
Water Conservationist	3.25	4.00	0.75
DNA Technologist	3.50	4.25	0.75*
Neurologist	2.75	3.50	0.75
Archaeologist	2.88	3.63	0.75
Health Toxicologist	3.00	3.71	0.71**
Civil Engineer	2.75	3.38	0.63
Inventor	3.00	3.63	0.63
Nanotechnologist	2.13	2.75	0.63
Environmental Toxicologist	3.00	3.50	0.50
Exercise Physiologist	3.38	3.88	0.50
Nutritionist	3.50	4.00	0.50
Optometric Technician	2.88	3.38	0.50
Paper Chemist	2.13	2.50	0.38

Regarding participation in the IAD project, teachers interviewed during the first year of the project found the Ford PAS teachers guide to be comprehensive. At the same time, they reported modifying the activities to fit their students' needs (e.g., due to students' lack of academic readiness) and their schools' requirements (e.g., time constraints or fitting into existing deadlines for standard curricula). Teachers felt that students enjoyed the Ford PAS activities and were interested in the subject matter. Finally, teachers mentioned challenges collaborating with one another using the MLive software (i.e., due to time constraints and a cumbersome reservation process).

CONCLUSIONS

Involvement in IAD had moderate positive effects on students.
Students' knowledge of some STEM careers increased. Additionally, students learned about how STEM subjects are related to one another and what is required in undertake careers. Some students became more interested in pursuing STEM-related careers.

Further research is needed to conclusively determine the effects of Ford PAS on students' scientific reasoning skills and there was not an association between IAD and students' STEM attitudes.

Involvement in IAD had positive effects on teachers.

Teachers felt more prepared to teach relevant skills to students and they were more comfortable integrating non-STEM subjects into their science teaching. Teachers also felt more comfortable about supporting students' knowledge of what professionals in a variety of STEM careers do for their work. However, IAD did not impact teachers' overall attitudes about using technology in the classroom.

Considerations

In areas where no impact was measured, it is possible that because participating students and teachers already had positive attitudes, a ceiling effect was created, reducing the chances of any improvement. In addition, the phenomenon of "experience limitation" may be relevant. Students in programs such as IAD often overestimate their knowledge or perceptions about STEM subjects on the pre-tests (Nimon, Zigarmi, and Allen, 2010). Later, because of their experiences during the program, students develop a more realistic perception and hence give lower ratings on the post-test.

During the first year of the program, teachers identified some challenges with program implementation. Specifically, teachers mentioned the timing and the extent to which the curriculum was used in the classroom, the challenging reading level of the student materials, and difficulties related to using technology resources. These challenges may have contributed to no change or minimal attitudinal change.

Lastly, there could have been evaluation measurement issues in the modestly scoped study. Research on other evaluation studies suggests that it is often challenging to assess student interest and to make generalized statements about the effect of STEM education programming (UMass Donahue Institute, 2011).

Research shows that various indicators of student interest and self-confidence in science and math in high school are strongly associated with students continuing with STEM studies through college, above and beyond enrollment and achievement factors (Maltese & Tai, 2011). This was the case in the IAD program in that it helped maintain students' interest in STEM fields. Future iterations of the program may focus on *increasing* the interest and self- confidence of the students in STEM fields. A few recommendations to achieve this goal are:

- Achievement in a certain field helps boost a student's interest and self-concept in that field (Beier & Rittmayer, 2008). The IAD project staff may wish to add an aspect of achievement/competition to the IAD program. Similar programs in the past have used experiences such as Robot building contests to encourage healthy competition.

- Research has shown that out-of-school participation in STEM activities boosts/enhances STEM achievement in school. The IAD staff may wish to support program efforts with an out-of-school component. For instance, there could be an afterschool club and there could be a parent component. Parents or other role models could be encouraged to get involved in helping students cultivate and sustain interest in STEM fields.

Although reducing the gender gap in attitudes towards STEM was not a specific goal of the IAD project, project staff may wish to consider having future curricular activities address girls' lack of interest in STEM. This is warranted given the contrast between boys' interest and girls' lack of interest.

- Finally, the IAD program staff may wish to consider adding a summer component for students, in addition to the year-long activities. Research indicates that the intensive nature of the summer programs often works to achieve the student outcomes set forth by programs such as IAD (Hayden, Ouyang, Scinski, Olszewsk, & Bielefedt, 2011).

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