ACTION RESEARCH

SYNOPSIS OF FINDINGS

DoD Career Scientists' and Engineers' Impact on Middle School Students and Science Teachers

Department of Defense
National Defense Education Program
Pre-Engineering Program

2008 & 2009 Evaluations of *IDCP: Inquiry-and-Design Curriculum with Partnerships*

Harford County Public School District (Maryland)
Aberdeen Proving Grounds Army Research Laboratory

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The data from two independent rigorous program evaluations with different student populations over two years in Harford County (Maryland) School District and Aberdeen Proving Ground Army Research Lab strongly suggest that Career DoD Scientists and Engineers in the classroom occupy a distinctive role and represent a powerful asset within the portfolio of STEM education programs supported by the federal government.

Results of the 2008 and 2009 Program Evaluations[1] of the "Inquiry and Design Curriculum with Partnerships Intervention"[2] (IDCP)[3] strongly suggest that **Career DoD Scientists and Engineers collaborating with 8th grade teachers in the classroom over several weeks to deliver an inquiry-and-design problem-solving curriculum:**

- **Significantly increase students' science knowledge gains compared to both Comparison Group gains and the regular science curriculum (Graphs 1-2);**
- **Significantly increase students' abilities to apply scientific procedures to successfully reason and write rubric questions (Graph 3);**
- **Significantly increase both students' abilities and their confidence to use inquiry-and-design procedures to successfully problem-solve (Graphs 4-9);**
- **Increase students' interest and engagement in science (Graph 10, verbatims p. 9-12);**
- **Increase teachers' science knowledge, and frequency of teaching inquiry skills; (Graphs 12-13, teachers' verbatim comments pp. 8-9);**
- **Increase students' interest in considering pursing careers in the STEM field by: (Graph 11, teachers' and students' verbatim comments, pp. 8-12);**
  - **"Putting a friendly face" on the seemingly impersonal, distant world of science for students; thus, making a STEM career seem more accessible;**
  - **Providing a unique, effective, vivid, and reinforcing "human interest" conduit for students to interactively learn why it could be interesting to have a career in the STEM field;**
  - **Building positive, supportive working relationships between students and career scientists and engineers over time, with S&Es not being directive (as teachers often are), but instead, interested in the students' thinking and problem-solving processes; helping them to more effectively use reasoning and the scientific process by asking guiding questions, and, thereby, model and demonstrate the value and intellectual excitement of scientific inquiry;**
  - **Integrate throughout the IDCP curriculum stories from their intriguing life experiences and interesting careers, focusing on the value of learning from error, their use of the scientific process to solve "real life" problems, and applying higher level science inquiry skills -- which all contribute to making the discipline come alive and exciting to students.**

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[1] *A brief summary of the methodology and sample demographics for 2006, 2008, 2009 - Appendix A, p 13.*

[2] *IDCP's Inquiry-and-Design Curriculum = Materials World Modules Sports Materials module with DoD S&Es.*

[3] *For full methodology and results see Action Research's **2009 Program Summative Evaluation Executive Summary**; **2008 Process Evaluation**; **Best Practices Guide: Integrating DoD S& Es into Middle School Classrooms via NDEP STEM Learning Modules**; **2006 Summer Institute Program Evaluation**.*

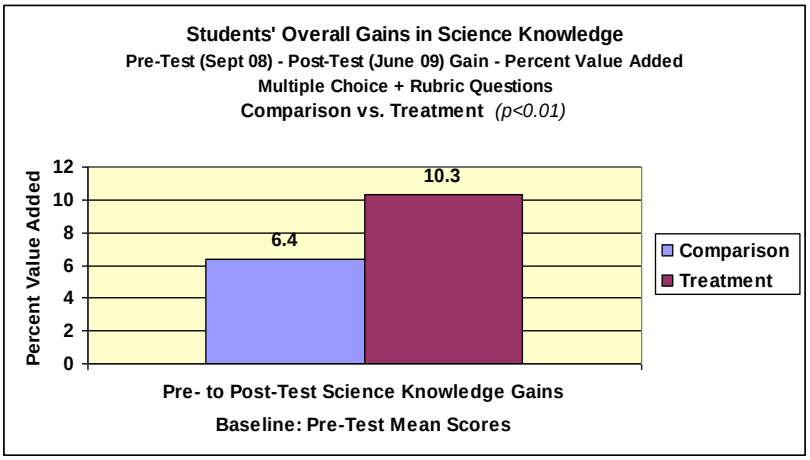
Quantitative Evidence

Students' Knowledge of Science

Scientifically-gathered, research data from the rigorous 2009 quasi-experimental design evaluation of IDCP – which replicated many of the 2008 evaluation's results -- strongly suggest the following:

- **Students trained with an *Inquiry and Design Curriculum with S&E Partnerships (IDCP) in the classroom made statistically significant science knowledge* (*p<0.01*) *gains* over students in the Comparison Group. (10.3% Percent Value Added[4]-PVA vs. 6.4% PVA, respectively) This reaffirms previous findings in 2006 and 2008, that IDCP provides significant Value Added over the regular curriculum.** (Graph 1 below)

Graph 1: Students' Gains on Science Knowledge Tests – September 08- June 09



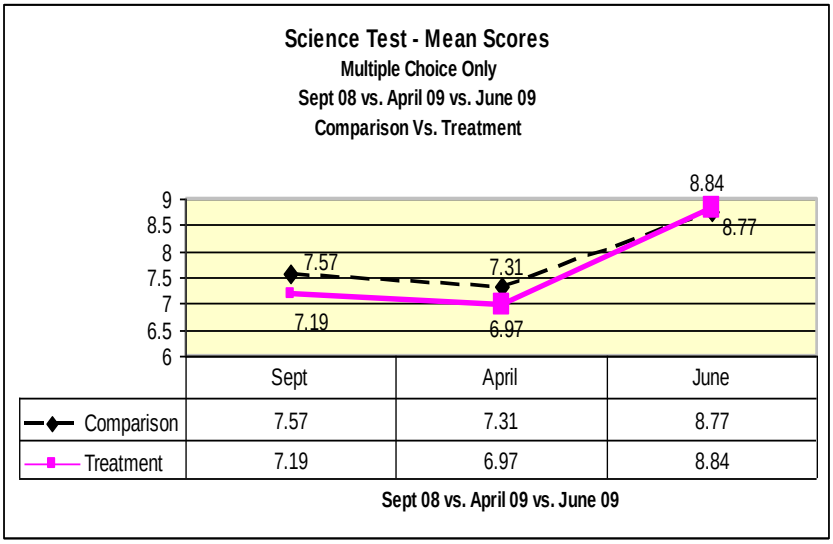
- **When students learned via Inquiry and Design Curriculum working with Career S&Es in the classroom, the Treatment Students' significantly increased their gain in science knowledge, as measured by June test scores compared to September.** (Graph 2) The same test was administered to all students at three intervals – September 2008 (baseline pre-regular curriculum instruction scores), April 2008 (post-regular curriculum instruction and post- Eighth Grade State Assessments); and June 2009, after Treatment students were taught with IDCP, and Comparison Group were taught with textbook and other off-the-shelf modules. The Knowledge test was professionally-built using psychometrics (*reliability .64 Chronbach's alpha)* by psychometricians who have worked at Iowa Testing Program, a subsidiary of American College Testing, DoD's Armed Services Vocational Aptitude Battery (ASVAB), and NAEP, the National Assessment of Educational Progress. (Each test item was mapped against State Standards, District 8th grade science standards, the textbook and MWM Sports Materials text. District Science Supervisors reviewed each item and verified the 22 items (20 multiple choice and 2 rubric) should be answerable by both Comparison and Treatment students through their regular instructional processes.)

[4] *To determine the Value-Added of students learning science with the IDCP Intervention compared to the regular science classroom approach, the Percent Value Added was calculated. PVA, along with standardized mean gain effect and normalized gain (in 2009 report) are generally used by educational evaluators and the U.S. Department of Education. The equation for computing Percent Value Added (PVA) for a group is:*

$$\frac{\text{Post-Test Mean Scores - Pre-Test Mean Score}}{\text{Pre-Test Mean Scores}}$$

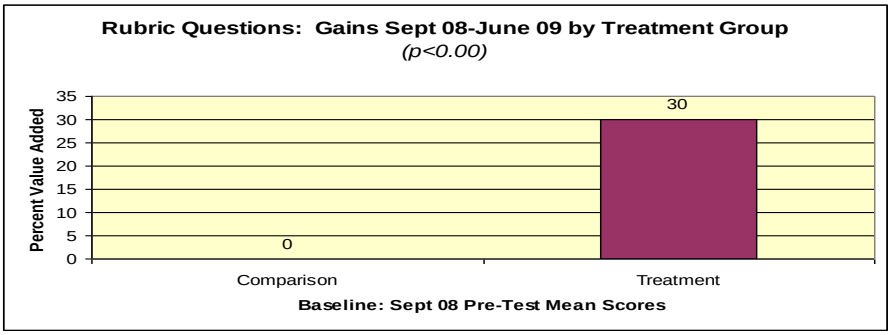
- **This statistically significant gain in science knowledge in June 2009 occurred despite the Treatment Group's lower average pre-test scores in September 2008 and lack of gain in April 2009 using the regular curriculum.** (Graph 2)

Graph 2: Students' Scores on Science Knowledge Tests – September 08 vs. April 09 vs. June 09



- The 2009 data replicate the 2008 data that S&Es interacting with students working in teams on with Sports Materials labs perform statistically better on writing correct short answer rubric questions than do Comparison students.
- **Treatment students working with S&Es and IDCP *Sports Materials* curriculum <u>significantly improved their ability to write effective answers to open-ended rubric questions over Comparison--demonstrating a stronger ability to express and apply the scientific method</u>, an important skill for State Testing** [5] (30% PVA vs. 0% PVA, respectively, *p<0.00*) (Graph 3).
- **Comparison Students, after working a year with the regular science curriculum and studying off-the-shelf modules, showed no improvement in their average ability to write well- reasoned short answers applying the scientific method.**
- **The career S&Es' impact in interacting with students and working with student teams to coach them and guide their reasoning to apply the scientific inquiry process appears to be a strong component of the statistically significant gain in this highly important skill.**

Graph 3: Gains on the Rubric Questions September 08 to June 09 – by Treatment Group



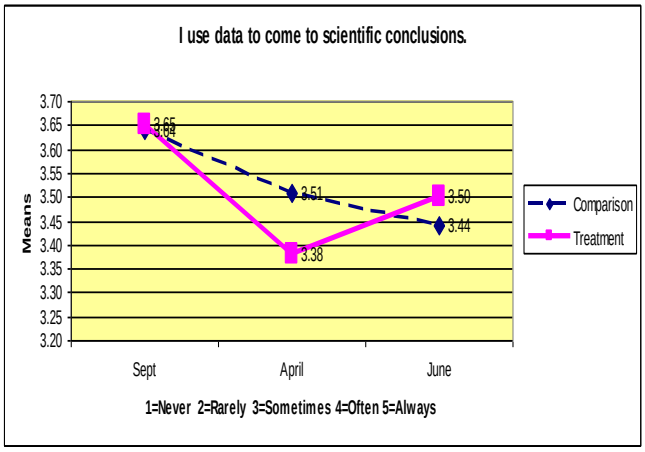
[5] *Rubric essays were scored by an independent professional essay scorer who has done such work for ETS and other testing firms. The scorer did not know the treatment group students were assigned to.*

Students' Problem-Solving and Inquiry and Design Skills

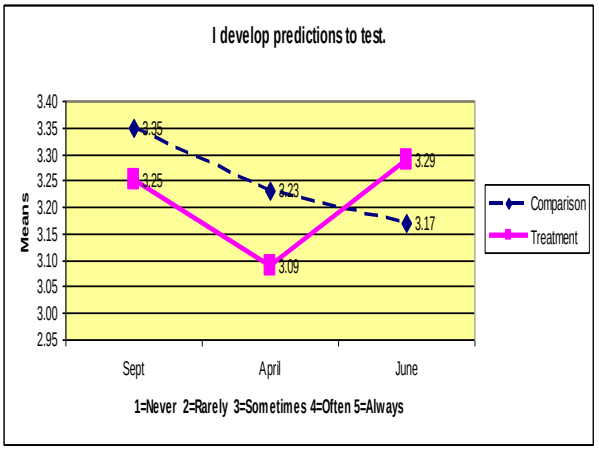
Changes in students' attitudes, inquiry-and-design and problem-solving behaviors Pre- to Post-IDCP were assessed through a battery of self-report questions, administered via web surveys. Many of the questions were also asked of Teachers and S&Es to verify students' responses.

- Working with the Career S&Es and Inquiry and Design Curriculum (*MWM Sports Materials*) Treatment Students made significant gains in more frequently using problem-solving and higher lever inquiry science skills with IDCP *Sports Materials*, compared to both the Comparison students (June 2009 - 3.50 vs. 3.44, respectively) and the regular science curriculum.
- As demonstrated by Graphs 4-9, although the Treatment students did not perform problem-solving skills or inquiry/design skills as often as the Comparison using the regular curriculum for 8 months (September 2008-April 2009). However, when **using IDCP they surpassed the Comparison students on multiple dimensions of problem-solving and inquiry skills.**
- **These results replicate the findings in the 2006 Evaluation** *(p 50-51) and the* ***2008 Evaluation****, (pp. 63-70).*

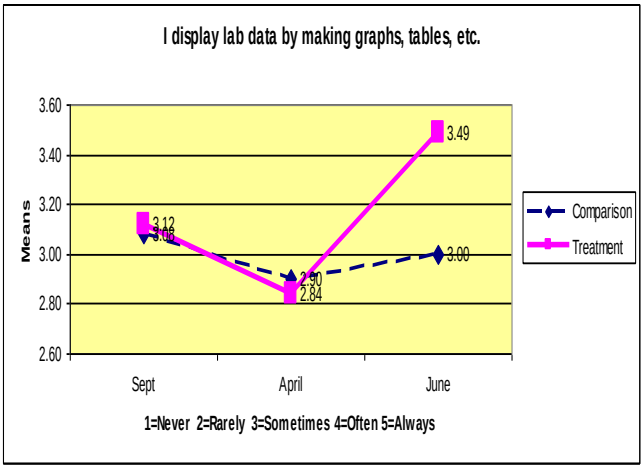
Graph 4: I use data to come to scientific conclusions.



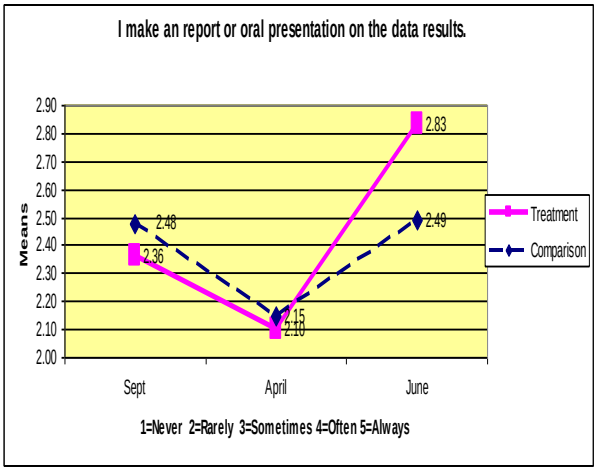
Graph 5: I develop predictions to test.



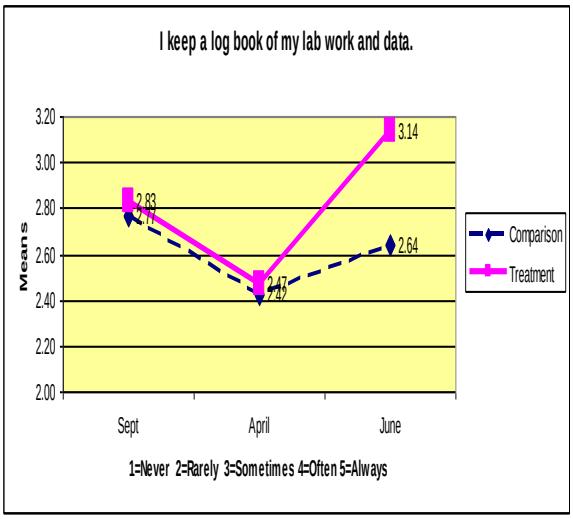
Graph 6: I display lab data by making graphs & tables, etc.



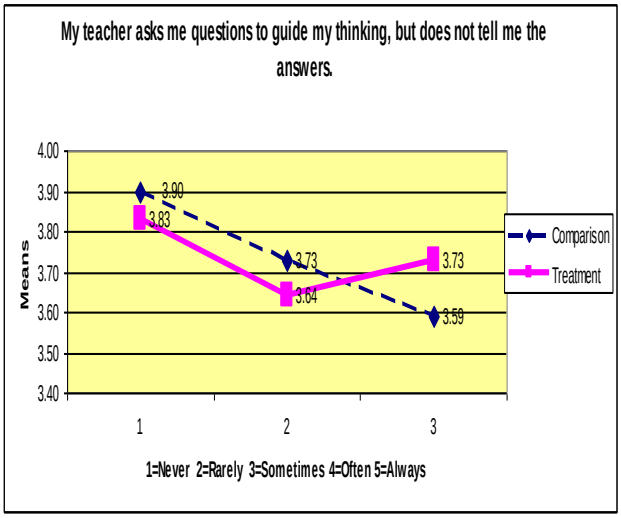
Graph 7: I make an report or presentation on the data results



Graph 8: I keep a log book of my lab work and data.



Graph 9: My teacher/S&E asks me questions to guide my thinking, but does not tell me the answers.



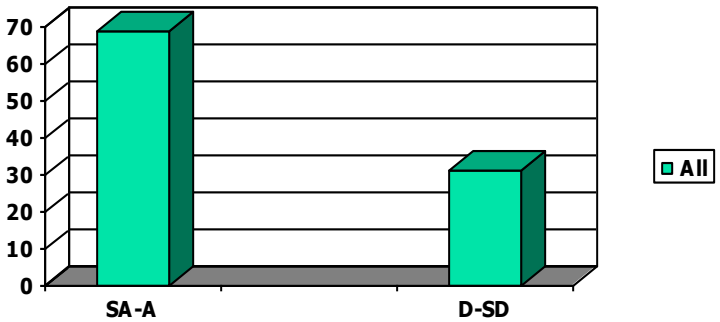
Students' Interest in and Engagement with IDCP

Changes in students' attitudes and behaviors pre- to post-IDCP were assessed through a battery of self-report questions, administered to students via surveys. In Graph 10, students were asked if they agreed or disagreed with a series of statements. Using a Likert scale, *"SA-A"* indicates *"Strongly Agree-Agree"* and *"D-SD"* means *"Disagree-Strongly Disagree."*

To triangulate (cross-check and validate) the data, a similar battery of items were also administered to the students' teachers and S&Es, asking them to assess the frequency they observed the students engaged in the various skills and tasks. (pp. 66-68, 2008 Evaluation). Overall, their results mirror and verify the students' responses. The 2009 results on students' attitudes, discussed in the full report, were mixed.

- **Learning with Career S&Es and the Inquiry and Design Curriculum, students significantly improved their attitudes toward studying science and encouraged a significant number of students to seriously consider science careers.**
- ***Between 60-88% of students agreed that MWM had increased their interest and motivation to study science, as measured by a series of questions.***
- **Students' and Teachers' responses to a series of questions about the IDCP curriculum and S&Es appear on pages 8-12 and confirm the quantitative results.**

Graph 10: I feel like I was more actively engaged in learning science with IDCP Sports Materials, than in my regular science class. (69% agree)



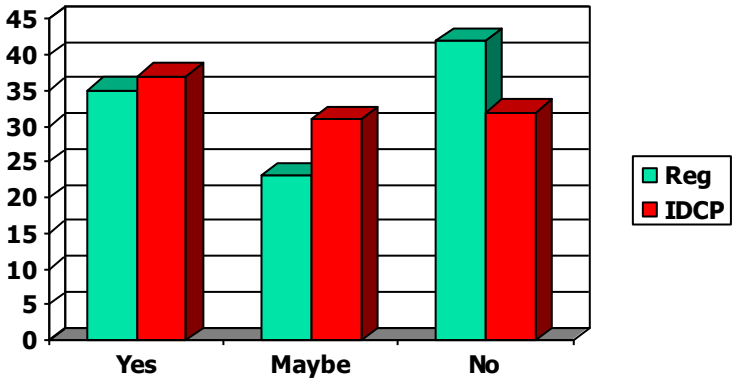
Students' Interest in STEM Careers

A key NDEP goal is to find an effective means to motivate more American students to enter the STEM field; therefore, it was of interest to ascertain if IDCP effected student interest in STEM careers. To measure changes in students' level of motivation, all 2008 and 2009 Treatment Students were administered pre- and post-IDCP surveys via the web in April and June. As part of the 2009 quasi-experimental design, both the Treatment and Comparison groups also took pre-survey in September 2008, and a post-survey in April 2009, to measure the impact of the regular science curriculum on students' STEM career motivations to provide a baseline for comparison.

- **Working with career scientists and engineers and an Inquiry and Design Curriculum (IDCP), students made significant gains in interest in pursuing careers in STEM in 2008.** (Graph 11)
- In 2009, the results demonstrated an increase in the number of students changing their level of interest in a science career in a positive direction, but were less robust. (see Tables 35-38 of the 2009 Evaluation Executive Summary)

Graph 11: Regular Classroom: Pre-IDCP: Have you considered a science career?

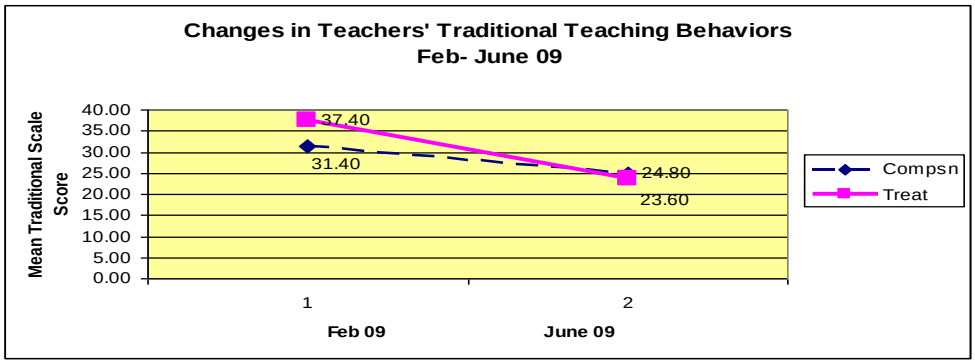
Post- IDCP: Has working with MWM Sports Materials and the S&E made a career in science/engineering



- Students were asked about their career aspirations both during their regular science classes via a Pre-Survey, and after experiencing IDCP on a Post Survey.
- When asked *during their regular science class* ("Reg"), **a plurality (42%) of students reported they were NOT considering pursuing careers in science.** (Graph 11)
- However, **after studying *Sports Materials* with S&E mentors,** the number of **students interested in pursuing a career in science and engineering *significantly increased by 10%*** -- from 58% to 68%. After working with IDCP, **3% of students who previously were undecided, were convinced to switch to "yes" they were interested in pursuing careers** in science and engineering.
- The **number of students rejecting careers in science and engineering dropped by 10 points**, from 42% to 32%.

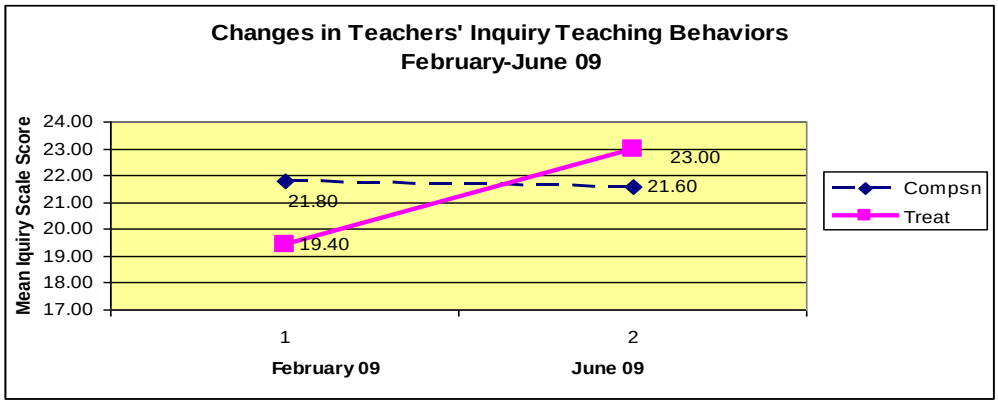
Changes in Teachers' Abilities to Teach Students Problem-Solving and Inquiry and Design Skills

- **The 2009 results confirm the 2006 and 2008 Evaluation findings that IDCP has the desired impact on teachers encouraging them to increase their student-centered inquiry-and-design teaching behaviors and decrease reliance on traditional teacher centered behaviors.**
- Analysis of the middle school teachers' results suggests that working with Career S&Es and IDCP encouraged Treatment teachers to **decrease their reliance on Traditional Teacher-centered Behaviors** such as being directive with students, giving "cook book" labs assignments, immediately telling students when they were wrong, etc., from 37.40 in February 2009 with the regular curriculum to 23.60 using IDCP in June 2009. (Graph 12)
- ***Graph 12: Teachers' classroom behavior: Traditional Teaching***



- The Comparison teachers used more student-centered higher order Inquiry teaching behaviors during the regular curriculum in February 2009 than did the Treatment Teachers (21.80 vs. 19.40, respectively)
- However, **working with Career S&Es and IDCP caused the Treatment teachers to strongly increase their student-centered higher level Inquiry teaching behaviors** to include having students create graphs to find patterns in data, to make presentations, defend their findings, learn from errors, and challenge each others' thinking. (Graph 13)
- **Therefore with S&Es in the classroom working with IDCP, teacher effectiveness improved and provided students with many more frequent opportunities to engage in higher-order science inquiry and problem-solving skills than in the regular science curriculum.**

Graph 13: Teachers' classroom behavior: Inquiry Teaching



Qualitative Evidence

Qualitative evidence is a critical part of a mixed-methods evaluation design. It is part of the data "triangulation" process, in which various data sources are used to better understand complex phenomena. The triangulated data may converge to create a single cohesive picture, or may diverge to reveal a more complex pattern of relationships. As such, qualitative data provides a means to potentially validate quantitative results, as well as to better interpret the data to gain deeper understanding of the results' implications.

As part of the triangulation process, students were asked their opinions about their experience with S&Es in the classroom via a web survey. Their teachers were surveyed about their observations of their students working with S&Es, as well as their own experiences partnering with S&Es in the classroom. The Teachers' reactions are presented first, since they represent the "outside third party" observing the student-S&E interactions. Next, the students' voice their own experiences of working with S&Es. Additional opinions about IDCP are summarized in the 2009 Summative Evaluation Executive Summary and full report.

TEACHERS

Teachers' Observations About Career S&Es' Impact on Students, their Teaching and Knowledge:

- The 20 Treatment Teachers involved in the 2008 and 2009 evaluations of IDCP with different populations of students in more than 70 classrooms, strongly valued, took advantage of, and integrated into the curriculum the DoD Career S&Es' deeper knowledge of science principles.
- Teachers encouraged and supported the S&Es' telling students' about their "real life" experiences providing demonstrations and examples of an exciting science career relating them back to the IDCP curriculum the students were experiencing.
- Treatment teachers in the 2008 and 2009 evaluations who worked with the DoD Career S&Es in the classroom observed that repeated weekly visits by the same S&E helped build a relationship and rapport between the scientist and the students, increasing the students' acceptance of his/her wisdom and feedback, providing a strong role model for students, thereby increasing his/her effectiveness in interesting students in the scientific process.
- Teachers contrasted the success of the IDCP Career S&Es' repeated-visit IDCP experience for their students, against the more traditional one-shot visit during "Career Day" or doing a science demonstration, and they observed that the IDCP Intervention was much more effective on a number of dimensions. (See below for a sample of verbatim comments).

Treatment Teachers' Verbatim Comments re: the DoD Career S&E's Impact:

> *[Having a Career S&E in the classroom] definitely provided me with the opportunity to* ***increase my knowledge of the subject*** *and to* ***[learn from] the experiences he has on a daily basis at his job***.[6]
>
> *My S&E worked very well with students this age. He was able to* ***bring credibility to the program*** *and convince them that* ***creative thinking is very important to science and progress***. *His* ***role as a role model can not be stressed enough***. ***They enjoyed his influence***.
>
> *My S&E has been a valuable resource to my classroom. He serves as a* ***role model, coach, mentor, etc****.... After a few visits the students started to respond to him warmly and began asking questions. Students who are considered gifted can ask him questions that I may not be able to handle as well as he. This* ***gives my students many opportunities to differentiate their learning and also a chance to consider future career possibilities with someone who has experience in the scientific community***.

[6] Verbatim comments have been lightly redacted to enhance readability, and bridge sentence fragments; the meaning is not altered.

*The **students developed a mental connection and "chemistry" [with] our S&E and saw how science, too, can be interesting**.*

*I wanted the students to see that **women can also be scientists and engineers**.*

*The students were able **to see [with the Career S&Es) how their science knowledge would apply to a job in the real world**.*

*I think they provided the students with the idea that **there is no stereotype that fits the scientist label**. I think the students **gained a lot from speaking with and seeing someone -- a "real world" scientist -- different in the classroom -- with a science background and profession**.*

***Students enjoyed meeting a real scientist. He provided us with direction and expertise**.*

*He provided **great insight into how the concepts I teach are applied in a real world setting**. He provides me another voice to echo my ideas to students.*

*He acted like a co-teacher, **filling in the gaps where I was having trouble giving the reasoning behind some of the more difficult topics**.*

*[Having a career S&E in the classroom] **provides the students a chance to question real world job criteria and expectations, as well as have a subject-specific knowledge base** other than the teacher.*

*He was very hands-on and **was able to ask guiding questions that were not too hard for the kids to understand and then help them generate their own answers**.*

*[The Career S&E] provided **demonstrations and hands on work that is exciting and different. Also, he provided life experience and work experience!!***

*Some of my students would wait until the S&E's return to ask her questions about random things I couldn't answer. **Her passion for science was contagious, and she was a great role model for the girls in my class**.*

STUDENTS

Students' Observations about the Career DoD S&Es' Impact on Them and their Classroom Science Instruction:

- Of the **1,178 Treatment students who experienced working with Career DoD S&Es in the classroom** in the 2008 and 2009 evaluations of the Inquiry and Design Curriculum with Partnerships Intervention (IDCP), **85% reported liking having the DoD S&Es involved with them in the classroom once or more a week over 4-5 weeks and felt they had been positively impacted on a number of dimensions by the experience.**
- When **DoD S&Es work with students over several visits on an inquiry-and-design, problem-solving curriculum** (like *MWM Sports Materials),* **they exert a strongly positive influence on students' enthusiasm for and interest in science, over the regular science curriculum.**
- Students reported they particularly found the information that the S&Es provide about their careers and work as scientists made them more interested in considering science careers themselves.

A sample of 2008- 2009 students' verbatim comments follow describing their experience with the Career S&. Of 1,178 comments, 85% were positive, 5% neutral, 10% negative:

*It was interesting **seeing an actual scientist**, and **not just the kind we see in movies**.*

*I liked getting to know how scientists work and **how they learn new things everyday!***

*I got to meet a real scientist and learn about science from him. **I really love science!***

*It was a **good experience to see what real scientists do in real life! He was cool!***

I liked ***that the scientists opened our minds to think in a different way.***

The scientist showed us and talked to us about the things she does in her job every day. *A lot of the things she told us about, we have done experiments with and learned about.* ***This shows us that having a job in the science world is not as hard to accomplish as we would imagine. She definitely made me think about a career in science.***

I liked that ***he had [real job] experience in what we were talking*** *about and studying, and* ***he could give some background information based on his work.***

I like the fact he took time off just for us. Also, ***he seems really interested in us having a job in science when we are older, and he is sort of persuasive. He did the best he could for the class and was a positive influence.***

When the scientist came in, ***she got to use really cool equipment that regular teachers can't use. These materials have really given me an interest in science.***

She gave us a better understanding of science. ***It was cool to know someone who really does science in their everyday life.***

I liked that ***I had someone in the classroom that could listen to my ideas and the questions we had to ask and talk about jobs in engineering.***

I liked hearing about his career, because I am considering a career in science and engineering.

The whole point of this (state assessment) testing is to see if we could have a future career in science. ***It was nice to see someone who actually did it and how they like it. It has also opened my eyes to all the different jobs involved with science.***

He seems to have a pretty cool job. When he showed us some of the things he actually worked on, like stab-proof fabric, I was interested.

I enjoyed having a Scientist work with us in our science class, because I felt somebody who has been working in this for a good portion of their life has a better understanding of the subject, and can go into much more detail *about specific things than our teacher.*

I enjoyed being able to discuss and inquire about topics in our class, like how cell phones were made and worked. ***The Scientist that visited us explained in good detail things that we would be interested in and showed how interesting scientific fields can be when in the right area.***

He was able to explain different things that he has done to solve problems as a scientist that we could do in our lab *He helped us figure out ways to make our prototype better.*

I like the fact he took time off just for us. Also, ***he seems really interested in us having a job in science when we are older, and he is sort of persuasive. He did the best he could for the class and was a positive influence.***

I liked that ***I had someone in the classroom that could listen to my ideas and the questions we had to ask and talk about jobs in engineering.***

What I liked about having a professional scientist in my classroom was the fact ***that he helped me better understand science and got me to think about what kind of career in science I can look forward to having.***

The scientist ***showed*** *you things to do, instead of* ***telling*** *you [like teachers].*

It felt like we were actually doing science for not just a grade but like something than he would have turned in. *So I liked it! I thought it was very fun* ***and that they should continue to do this.***

I learned a lot about his duty at Aberdeen Proving Ground. And I also learned a lot about how the materials he works on affect the environment. He was a great way to help me better understand science and materials!!!

I learned from the scientist that some things are so simple! It's right in front of your face, and you sometimes over-think the problem. Also, that not every project has to be a success at first--and trial and error is a part of science. I like having the scientist make us think of outside situations that we could relate to so we could better understand the concept he was teaching.

The thing I liked about the S&E was that he could explain things my teachers couldn't. He had a better understanding of what we were doing and gave a lot of helpful ideas to our project, ***he not only showed us ways to solve our problems****, but* ***he also showed us the steps to take in order to fix it. He knew a lot about the different materials we were using*** *and I was happy to have him help us with designing and testing.* ***He helped us by asking questions about what we were doing and helping us solve the answers instead of just leaving us with more questions and mistakes to make on our own, but he didn't do the work for us****, which was* ***helpful for us to learn on our own, but still have his help to figure it all out****.*

What I liked was that we actually got to have a ***scientist who does what we were learning for a living talk to as about what he does. It was interesting to learn about what exactly his job was****.*

What I liked the most about having an S&E come to my class was that ***he explained everything we were learning in class and explained it in terms that I could understand very easily****. Also if I didn't understand something I could just ask him a question and he would answer it fully and completely. I really appreciated that he took his own time to come to the classroom and teach us about sports materials.*

I liked that he was an ***expert and he really knew a lot of stuff that I liked to learn****.*

It was interesting for ***professional scientists and engineers to talk about science and what they specialize in****. The engineer* ***asked a lot of questions of the students to make them think and learn****.*

I liked that ***he could suggest questions that pointed out flaws and correct them, and that he contributed useful knowledge to our class****. He helped students to understand things and how to improve the project/labs they were working on.*

I liked how ***he led me through errors and problems that I had. To correct my errors, he showed me how to analyze data to show how scientists like him can solve everyday problems in the world. I believe that the help of this man has given me more knowledge of a future[career] and what I have to prepare for in High School****, and as a young growing adult.*

Although my science teacher was very helpful, ***the professional scientist and engineer knew much more about the particular things we were learning, since this was what he majored in. I thought his way of explaining things to the class was easier to understand then my teacher. I especially enjoyed when we talked about cell phones and sound waves, because it was interesting and scientific****.*

The scientist helped us see what we could do better. He asked questions that really got us thinking. He kept us interested in the topic. *He* ***told us about possible things we could do in the science field, which I found interesting****.*

I really liked Dr. X coming into our science class because he interacted with our group a lot and he helped us attain the ***answers to our questions, not by straight away giving them to us, but by asking us questions to find it ourselves. Also, it was pretty cool hearing about other science work done at APG****.*

He knew what he was talking about. ***I enjoyed having him watch what we did to see how we learned on our own. He was helpful.***

He knew the answers to some of the more complicated questions that our teacher could not answer. He could tell us about cool stuff that the APG is doing.

We got to see someone who works and deals with what we are learning. So we got to, in a way, relate to him.

I liked that ***he talked about the things he was working on, and what his job was.***

I like the fact that he blew things up

I liked how the scientist helped me with certain questions and ***helped me understand how to fix my mistake****. He helped me with my experiments a little bit each time. He also showed us some mathematical equations and showed us how to figure them out. Also,* ***he told us about the things you could do if we had a science or engineering related job in the future****.*

I thought he was really nice and he helped me and my peers ***understand physics a little bit better by explaining his job*** *and how to interpret what a ball is made of and how that affects the way it bounces or rolls. He also seemed eager to help us when we had a question when we were working on our lab.*

It makes me want to have a job in the science field!

I liked how she did experiments with us and showed us that science can be fun and not boring. I especially liked it when she taught us using fun ways like making ice cream!

He taught us how to build better thinking skills.

He asked questions instead of telling us the answers. His questions would help us better understand science after we answered the questions.

If the students had any questions, he answered them. He gave us answers and tips on how to improve our learning skills.

I liked having ***a second opinion from a well-trained, highly respected scientist****.*

I liked how ***he knew the answer to every question, but wouldn't come out and tell you the answer****.*

I liked how ***the he showed us there are many ways to learn about science, and how we can improve ourselves from learning from our errors****.*

It made me feel like I could be a scientist in the future*.*

Mixed, Neutral and Negative Comments (15%)

He was nice, but ***not very helpful****. He rarely worked with our group on Sports Materials.*

I didn't like having a scientist in my class. When we were talking, ***he made us work****.*

Well, our scientist was very kind, but he was ***using words and vocabulary that some of us didn't know****.*

Nothing*. (Several statements.)*

I didn't like it. He kept looking at my group, and kept *us on task.*

It was OK, but you ***could not understand*** *what in the world the man was saying.*

"Asdfl;kjfsd" – (gibberish)- Neutral (Several statements)

ACTION RESEARCH

Appendix

Multi-Phased Evaluation Objectives

A multi-phased, mix-methods rigorous evaluation of the effectiveness of NDEP's Inquiry-and-Design Curriculum with Partnership (IDCP) Intervention has been designed and conducted by Action Research & Associates, Inc. Using the same Program Evaluation Logic Model, and basic measurement instruments designed to answer the same core evaluation questions, the 2006, 2008 and 2009 studies have been designed to confirm or disprove the previous studies' findings.

Evaluation Methodology, Sample Description, and Brief Results: 2006, 2008, 2009

Phase I

Methodology: The **2006 Pilot Study was** conducted to evaluate a potential IDCP Inquiry-and Design materials science Curriculum – during a four-week residential Summer Institute at Garrett College (Maryland) with a sample of 82 middle and high school students, and six teachers; there were no S&Es. The study was an experimental design, controlled random trial (CRT) evaluation with a probability sample. It was a blind study, with students not knowing to which treatment group they were assigned. To select the sample, a two-tiered stratified random sampling process was used to create a probability sample to: 1) select the students from a pool of 401 applicants from across the State of Maryland, 2) assign the participants to a treatment group. The two-tiered stratified random selection process reduced the chance of bias potentially influencing the study results. Action Research developed a sampling model reflecting Maryland's demographics regarding race and sex, as well as being proportional to students' grade-levels and adjusted to the target sample size. Applicants were stratified by grade, race and sex, and randomly selected by matched pairs to fit the demographic proportions of the sampling model. Test and survey data from the matched Treatment and Control students was triangulated and cross-validated from multiple sources, including quantitative and qualitative data from teacher's web surveys, focus group results, and independent researcher classroom observations. Because the 2006 Summer Institute was a 24-hour, 7-days-a-week, 4-week residential science immersion program, during which the students received 3 hours of science instruction and 3 hours of math and technology instruction daily, it was important to determine if similar findings would result if the Inquiry-and-Design Curriculum was used in "real life" regular science classrooms during the school year. Since a defining feature of the NDEP PEP program is to forge partnerships between classroom teachers and DoD S&Es, it was also important to begin building an evidence base regarding the effectiveness of those partnerships.

Sample: The resulting stratified randomized matched sample of 82 students (41 per treatment) was balanced by Gender and generally reflected the Racial proportions found in Maryland's population: 56% White, 33% Black, and 10% Hispanic/Asian/Other. Students were from a wide range of socio-economic backgrounds (facilitated by DoD sponsorship of the institute and provision of student stipends); and represented a cross section of inner city, urban, suburban and rural school districts in Maryland.

Results: The 2006 study produced encouraging statistically-significant results suggesting that students learning with hands-on, **Inquiry-and-Design Curriculum - materials science modules learned significantly more science** (42% Percent Value Added vs. 26% PVA, Treatment to Comparison, $p<0.0001$) and **measurably improved their attitudes towards studying science** (13.9% vs. 3.3%, respectively, $p<0.07$) compared to Control Group students. (See pages 43, 50, 53-55 of the 2006 Evaluation Report for details of IDCP's impact on Students and Teachers.)

Phase II

Methodology: The "real world" site designated for the **2008-2009 Phase II Evaluation** was Harford County, Maryland. DoD selected 8th grade classrooms in Harford County Public Schools (HCPS) for several reasons. First, Harford County is the site of the Aberdeen Proving Ground (APG), a large Army Research Laboratory with a history of community outreach in STEM education. Second, HCPS has shown a strong interest in improving STEM education as the result of an on-going DoD base realignment that will bring thousands of additional S&Es to the area. Third, HCPS administrators and teachers had helped pilot the dissemination of the Inquiry & Design Curriculum - *MWM*

Sports Materials and other learning modules during the 2004-05 school year. Fourth, Harford Community College had received a DoD grant to support STEM teacher training.

The Phase II evaluations build on the same Program Evaluation Logic Model, quasi-experimental design approach, with triangulated data sources and measurement instruments developed for the 2006 evaluation. Phase II was developed in two stages:

Stage I, the **Process Evaluation** occurred **Spring 2008**; and

Stage 2, the **Summative Evaluation**, during the **2008-2009** school year.

Both Stages assessed the effectiveness of the NDEP PEP Inquiry & Design Curriculum with Partnerships (IDCP) Intervention. The I&D Curriculum evaluated was *Materials World Modules Sports Materials* combined with a Partnership formed between a DoD Scientist-Engineer (S&E) and an HCPS eighth grade science teacher. The students were exposed to IDCP in science classes an average of 15 hours, over 20-29 days; S&Es visited each school an average of one day a week for 4 weeks. For details, see the *Description of the Intervention,* page 13 of the 2009 Executive Summary. A number of key factors shaped the decision to conduct the Phase II evaluation in two stages:

Stage 1: 2008 Process Evaluation of the IDCP (without a Comparison Group) created an important opportunity to train teachers while also enabling them to gain classroom experience with IDCP in the classroom. It allowed for the refinement of 2006 instruments and the development of new instruments to measure program impact related to DoD S&Es, and the impact of the S&E-Teacher Partnerships on Students and Teachers. The Process Evaluation provided an opportunity to provide evaluative feedback regarding the program trainer (CASE for Learning) and to identify best practices for effectively integrating S&Es into an 8th grade classroom through empirical research, independent observation and student, teacher and S&E feedback. Lastly, it gathered data via web surveys on students, teachers and S&Es to provide initial Outcomes data to prepare for the Summative Evaluation.

A rigorous Summative Evaluation requires a pre-test for all students – both Comparison and Treatment – *before* they are exposed to the science concepts taught in *Sports Materials*. However, during Fall Semester 2007, HCPS 8th graders had been taught the target science concepts via their regular textbook. It was, therefore, impossible to get valid baseline pre-test data in January 2008 when DoD funding became available. This made it impossible to have a valid Comparison Group against which to compare the Treatment Group's performance. Therefore, DoD approved conducting a Process Evaluation in Spring 2008 to strengthen IDCP classroom implementation.

Sample: With no Comparison Group available in Spring 2008, the Process Evaluation measured changes in the same students, teachers and S&Es before and after they experienced the IDCP Intervention in May-June 2008. The non-random sample of teachers who volunteered to participate and their students was comprised of a total of 532 HCPS eighth grade students in 30 classrooms in two middle schools, 15 eighth grade teachers, and 14 DoD S&Es (one S&E covered 2 teachers). As a result, the sample reflected an eighth grade student sample balanced by gender, virtually half 13 and half 14-year-olds, and reflecting the Harford County racial demographics of approximately 84% White,6% Black, 4% Asian, 5% Hispanic, 1% Multi-Racial, and largely middle class.

Results: ***Students' Science Knowledge Gains:*** Overall, ALL student groups made significant gains (27% Percent Value Added[7] PVA *p<0.000000006*) in Science Knowledge through IDCP's Sports Materials Intervention with S&E/Teacher Partnerships. On average, traditionally under-performing groups in science -- Girls, Hispanic-Americans, African-Americans, and IEP Students -- learned significantly MORE science using IDCP. (See 2008 Process Evaluation Report for graphs and full discussion.) ***Gains in Students' Interest in Science:*** When asked a series of questions about their experience with IDCP, on average, two out of three students reported they agreed or strongly agreed that IDCP had had a positive effect. For example, two-thirds of students agreed or strongly agreed they liked learning science through the IDCP Sports Materials curriculum

[7] *See the footnote on p. 2 of this report for a definition and formula for Percent Value Added (PVA)*

Stage 2: 2008-09 Summative Evaluation was designed to be a **"real world" evaluation of IDCP, conducting a quasi-experimental design study, with students and teachers divided into Comparison and Treatment Groups.** Scientifically-gathered data were gathered via web surveys on changes in students' science content knowledge and attitudes toward science and problem-solving and inquiry and design behaviors; on changes in teachers' classroom behavior, use of inquiry-and-design versus traditional teaching behaviors, and the impact of S&Es on students and teachers. Student pre-test/survey data were gathered on 858 new 8th grade students, divided in to Comparison and Treatment Groups in September 2008. They were tested again in April 2009, after the eighth grade Maryland State Assessments, immediately before implementation of the IDCP intervention in May and June 2009. They were post-tested in June 2009 after IDCP exposure in order to be able to calculate the relative gains that Comparison versus Treatment students' experience. Comparison and Treatment Teachers and S&Es were surveyed pre- and post-the IDCP experience, and changes measured in their attitude, perceptions and classroom behaviors.

Sample: Since the Summative Evaluation was conducted in a "real-world" context – in 47 eighth grade science classes in a public school district during the regular school year -- certain contextual constraints were imposed on the study. Similar to almost all "real world" educational research, due to school district policy and practice, an active community of parents, and a strong teachers' organization, it was not possible to randomly select teachers/classrooms to the study or randomly assign them to treatment group. Therefore, the Treatment teachers were a self-selected sample of five. The Harford County Science Supervisor selected and recruited five "comparable" teachers and schools to form the Comparison Group to "match" the 5 Treatment teachers. Due to available resources, the study was conducted in one school district and the adjacent Army Research Lab-Aberdeen Proving Ground. This resulted in a relatively large, non-random student population (858) and 47 classrooms, but a somewhat small, sample of teachers and S&Es who volunteered to participate. Therefore, careful analysis of the Treatment and Comparison student and teacher groups' demographic data reveals many important similarities between the two treatment groups -- but also some noteworthy differences that appear to have impacted some results. Those similarities and noteworthy differences are briefly presented below. For a more detailed discussion, please refer to the full 2009 report.

Students: Overall, in 2009 a total of 1097 eighth grade science students in 47 classrooms in six Harford County middle schools taught by 10 science teachers and 5 S&Es comprised the total sample. (Tables 1-5, pp. 15-17- 2009 Summative Evaluation Executive Summary.) Of these, 557 were Treatment students who were exposed to the *Inquiry & Design Curriculum Sports Materials* module daily a minimum of 15 hours (4-5 weeks), delivered by their teachers partnering weekly with a Scientist and Engineer. The final study sample of 453 Treatment students and 405 Comparison students who completed all four parts of the study -- pre- and post-IDCP science tests and pre- and post-IDCP surveys, and who, therefore, had complete records -- formed the final study sample of 858.

Both Treatment and Comparison Groups had similar sample distribution patterns by Gender, Age and Race, varying no more than 2 points from each other on the variables. Both treatment groups were evenly split boys and girls, and virtually all (97%) students were 13 and 14 year olds. The overwhelming majority of the students in both groups were White (72.2%-Treatment vs. 69.9%-Comparison), as is Harford County.

Regarding the socio-economic status (SES) range of the four middle schools *within* each treatment group, there are fairly wide differences in the average percent of FaRMS students that attend each school, ranging between only 7.7% (Fallston Middle School) to 46.3%. (Aberdeen MS). FaRMs data indicates the percent of students economically qualified for and receiving Free and Reduced Meals (FaRMs). FaRMS data is useful as a proxy for gauging the relative socio-economic status (SES) of the schools' student body. FaRMs data provides an *inverse* estimate for student socio-economic status: the *lower* the percent of FaRms students, the *higher* the school's average student population's SES. However, comparing the mix of middle schools included in both treatment groups and averaging the percent of FaRMs students by School and Teacher, we find that the two samples are reasonably well-balanced. The Treatment Group schools had a slightly lower average percent of FaRMs students, therefore, they had the slight advantage of a relatively higher average socio-economic status (Comparison-23.3% vs. Treatment-21.1% FaRMs). However, the difference is only 2 points, so SES is unlikely to be a strong intervening variable between the two groups.

There were **some noteworthy differences** between groups, beginning with **self-reported Math and Science grades**. The Comparison Group reported more had earned "A's" in both subjects than Treatment did. (*Science* – 52.4% Comparison vs. 47.5% Treatment reported earning "A's": *Math*- 38.7% of Comparison students with "A's" vs. 32.3%) There was a **5-point and 6-point difference respectively, in favor of the Comparison Group.** The fact the grades were "self-reported" likely led to some "grade inflation," but, if so, that factor probably functioned similarly in both groups.

The data suggest that the **Comparison students were 6 points more likely than the Treatment students to want to attend a 4-year college** (77.0% vs. 71.1%, respectively, Table 4).

They were also **7 points more likely to plan to work** (20.2% vs. 12.2%, Comparison vs. Treatment) - **(some planning to work while they attend school)** which may link to the Comparison students' relatively lower socio-economic status and higher economic need, per FaRMs data (Tables 2 and 4).

Although speculative, these two factors together -- the larger percent of Comparison students interested in pursuing a 4-year college degree and planning to work -- may suggest an average difference between the groups in ambition and/or aspirations to achieve, with the advantage to the Comparison group.

Teachers: A total of 10 HCPS eighth grade science teachers volunteered to participate in the 2009 Summative Evaluation. (Table 5) (Tables 5-6, pp. 18-19-2009 Summative Evaluation Executive Summary) Seven of 15 teachers previously trained in Spring 2008 with IDCP, continued to train and work with the program in 2009. Two of the 7 IDCP-trained teachers were not matchable due to teaching in unique circumstances (alternative schools, etc.) Therefore, the Treatment Group consisted of 5 Teachers, which were matched by the Harford County Science Supervisor with 5 "comparable" eighth grade teachers from similar middle schools. They taught 1097 students in 47 classrooms.

Both treatment teachers groups were similar on two dimensions – gender with 40% female/60% male - **and race** - both groups described themselves as 100% non-Hispanic Whites. (Table 5)

However, there were **notable differences, with most factors appearing to favor the Comparison Group:**

- **All Comparison teachers had earned Masters Degrees compared to 60% of the Treatment.**
- Three (60%) of the **Comparison teachers had earned degrees in Science**, rather than Education, compared to 2 (40%) of the Treatment teachers. (Table 5)
- All (100%) Comparison teachers, vs. 80%, Treatment, were **certified to teach science** in Maryland.
- **Comparison teachers had taught longer and were older on average**.
- **However, Treatment teachers taught students who were slightly higher socio-economic status**, as indicated by the schools' average Free and Reduced Meals (FaRMs) statistics (Table 2)
- **Class size:**
  - Treatment teachers taught a total of 557 students in 22 classes (avg 25.3 students per class).
  - Comparison taught 540 students in 25 classes (average 21.6 students per class).
  - **This would indicate Comparison teachers taught smaller classes, on average.**
- **Students' Average Maryland Science Assessment Science (MSA) Scores by Teacher** (Table 6)
  - Harford school officials decided that the IDCP intervention implementation would occur in May-June, after students' had taken the MSA science exam in 2009. Therefore, the MSA results do not reflect the impact of IDCP on the scores.
  - However, the MSA scores do provide another important indicator to explore and ascertain if the major differences between the Treatment and Comparison groups' performance on evaluation tests and surveys are due largely to differences in teachers' or students' abilities. To do so, it is of interest to look at the pattern of students' average MSA scores between teachers, between treatment groups and between 2008 and 2009.

- If certain teachers' students consistently score in the same range each year, then it can be reasoned that the difference likely is due to the teachers' abilities. If there are wide swings from year to year in a teacher's mean scores, then it is more likely due to changes in each year's students' abilities, with all else held constant.
- That said, analyzing the average MSA science scores by teacher for 2008, it can be speculated, that, all other factors being equal, **if the study had been conducted in 2008, that the Treatment students may have equaled or possibly out-scored the Comparison students on cognitive science tests** (409.46 vs. 404.89 mean MSA scores for all 2008 Treatment vs. Comparison teachers and their students).
- However, **in 2009, <u>that result or trend on the MSA's reversed itself</u>**, with the **<u>Comparison teachers and students scoring higher than the Treatment</u>** (415.79 vs. 411.55 mean MSA scores for 2008 Comparison vs. Treatment teachers and students).
- **The Treatment group**'s average scores in 2008-2009 **only changed 2 points**.
- However, the **Comparison Group changed more than 10 points** between 2008-2009. Specifically, **two Comparison Teachers** had average MSA score changes in 2008 and 2009 that **varied more than an average of 23 and 15 points each**, to have the highest scores of the sample.
- The question, therefore, arises--why did the large swings in the Comparison Teachers' Mean 2009 MSA scores occur? Did two teachers change student ability levels, and in 2009 begin teaching gifted and talented students? It is impossible to determine a cause from the available data.

- **Results**: ***Students' Science Knowledge Gains:*** Students trained with an *Inquiry and Design Curriculum with S&E Partnerships (IDCP) in the classroom made statistically significant science knowledge (p<0.01) gains* over students in the Comparison Group. (10.3% Percent Value Added[8]-PVA vs. 6.4% PVA, respectively) This reaffirms previous findings in 2006 and 2008, that IDCP provides significant Value Added over the regular curriculum. (Graph 1, p. 2, this report) ***Students' Science Knowledge Scores:*** When students learned via Inquiry and Design Curriculum working with Career S&Es in the classroom, the Treatment Students' significantly increased their gain in science knowledge, as measured by June test scores compared to September. ***Students' Ability to Write Effective Rubric Answers:*** Treatment students working with S&Es and IDCP *Sports Materials* curriculum significantly improved their ability to write effective answers to open-ended rubric questions over Comparison--demonstrating a stronger ability to express and apply the scientific method, and an important skill for State Testing [9] (30% PVA vs. 0% PVA, respectively, *p<0.00*) (Graph 3). ***Students' Ability to Problem-Solve and Use Inquiry and Design Skills***: Working with the Career S&Es and Inquiry-and-Design Curriculum (*MWM Sports Materials*), Treatment students made significant gains in more frequently using problem-solving and higher lever inquiry science skills with IDCP *Sports Materials*, compared to both the Comparison students (June 2009 - 3.50 vs. 3.44, respectively) and the regular science curriculum.

For more results and details, see this report, pp 2-12, and the 2009 Executive Summary pp. 22-44.

[9] *Rubric essays were scored by an independent professional essay scorer who has done such work for ETS and other testing firms. The scorer did not know the treatment group students were assigned to.*

Action Research & Associates, Inc.

Action Research & Associates, Inc., established in 1999, is a research firm based in the Greater Washington DC/ Baltimore metropolitan area, and serving the Nation and the World. The Principal Investigator for the multi-year mixed-methods Inquiry and Design Curriculum with Partnerships (IDCP) evaluation study is Dr. Kris Juffer, Executive Director of Action Research & Associates, Inc. Dr. Juffer is well-qualified to conduct the IDCP Summative Evaluation, since she has been a professional researcher and evaluator for more than 25 years, specializing in evaluating federal and state STEM education programs.

Action Research conducted the experimental design study of IDCP *MWM*'s effectiveness during the 2006 Summer Science Institute conducted at Garrett College with randomly-selected 6th-12th grade Maryland students. Action Research completed the Process and Outcomes Evaluation of IDCP (*MWM Sports Materials)* in 15 HCPS 8th grade classrooms in 9 middle schools during Spring Semester 2008, and has conducted the 2008-09 IDCP Summative Evaluation. Action Research is very familiar with the Harford County 8th grade teachers, schools, and science district-level staff, as well as the Aberdeen Proving Ground Scientists and Engineer mentors, and Harford Community College. Action Research has forged positive working relationships with all key participants, and worked closely with them to steer the process to successfully complete the Spring 2008 and 2008-09 evaluation studies.

Action Research & Associates, Inc., a small business, customizes each evaluation research project by building specialized teams ("Associates") of highly competent researchers from among the Nation's top researchers, to meet the parameters of each project. To accomplish the Phase II IDCP evaluation, Action Research assembled a special team: In addition to Dr. Juffer as the Principal Investigator, the team consisted of methodologists, psychometricians, statisticians, database experts, an expert in instrumentation, and science educators.

Additional experience relevant to the STEM Learning Modules -- Dr. Juffer is one of the few evaluators who has conducted evaluation research that the U.S. Department of Education has indicated meets the federal standards for "Scientifically Based Research-SBR." In addition, Action Research has conducted high caliber research and educational program evaluations for such clients as the National Science Foundation, the National Institutes of Health – Office of Science Education, U.S. Department of Health and Human Services, Centers for Medicare & Medicaid Services (CMS), U.S. Department of Education, the Public Broadcasting Service's (PBS) Kids *Ready To Learn* TV Programming (S*esame Street*, *Between the Lions*,) the Department of Defense's Educational Outreach Programs, U.S. Information Agency, the Fulbright Program, the Voice of America radio and television programming, Arbitron (national radio station ratings), CBS network television and radio, ABC network television, Clear Channel radio corporation, WAMC Northeast Public Radio (NPR), and other media companies; Prince Georges (MD) County Public Schools, Garrett (MD) College, the University System of Maryland's Chancellor's Office and other non-profit agencies, corporations, universities and school districts.

In addition, Action Research's staff includes experienced developers of tests and assessments the Armed Services Vocational Aptitude Battery (ASVAB) and the National Assessment of Educational Progress (NAEP). Dr. Juffer has conducted psychometric research for the Iowa Testing Program, a subsidiary of American College Testing (ACT), developing reliable and validated assessment instruments and achievement tests. She has also researched cross-cultural adjustment and developed a highly reliable (.95), nationally-recognized psychological test, the *Culture Shock Adaptation Inventory* (CSAI ©1983), with four unique subscales that contribute to an overall score measuring the degree of cross-cultural adaptation an individual experiences, which is considered a break-through in its field. Her work is recognized and used in many countries around the world.

With masters and doctorate degrees in education, Dr. Juffer has worked in education for more than 25 years, as a classroom teacher, district administrator, curriculum developer and coordinator, university professor, federal government program officer and senior official, contractor and professional evaluator. She has also conducted educational research, and media and communications research for local, state, national and international clients, and is fluent in Spanish at the professional level.