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Impact of Academic Performance Improvement (API) Skills on Math and Science Achievement Gains

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Dr. Wosu has developed and directed mentoring programs for preparing women and underrepresented college students for graduate education, and high school students for college careers. Since coming to the University of Pittsburgh, he has created several programs including the Pitt Engineering Career Access Program (PECAP), a program to increase the enrollment and retention of underrepresented and economically or academically disadvantaged students in engineering education and the Pre-PhD Scholars programs, to increase the numbers of underrepresented students earning doctorates in Engineering. Dr. Wosu also works to institutionalize initiatives that provide an inclusive and safe environment for all students—one that fosters effective multi-cultural interaction and communication, reducing the isolation of any group, and increasing the School's ability to provide equitable educational support services.

As an Associate Professor of Mechanical Engineering, Dr. Wosu has been an engineering educator for over 20 years. He is a graduate of the University of Oklahoma where he earned his Bachelor of Science degree in petroleum engineering. He earned a Master of Science degree in industrial and applied physics at the Central Oklahoma State University and a Master of Science degree and a PhD in engineering physics at University of Oklahoma.

ASEE Paper

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Abstract
The need to channel underrepresented minority students into the sciences continues to be a major national priority. Science, technology, engineering and mathematics (STEM) education in America is not yet achieving satisfactory results with traditionally underrepresented minority students. The high attrition rate of African Americans from the STEM pipeline has been identified as a greater barrier to increased representation than their attraction to non-quantitative fields. Critical thinking skills and self-directed inquiry are two areas that if enhanced at the entry level of science and engineering education, could possibly increase motivation for STEM careers for minority students when other barriers are addressed. There is a need within the curriculum for a process focused on how to effectively deliver the fundamental idea of the material to help the students learn and retain the core concept.

Critical and Analytical Reasoning Enrichment (CARE) program, here referred to as Project CARE, administered at the University of Pittsburgh identified analytical skill deficiencies and low motivation for mathematics and science courses at the pre-college level as major causes of the poor preparation and low enrollment of students from the underrepresented groups into science, technology, engineering and mathematics (STEM) fields. The project defines STEM A*cademic Performance Impact (API)* skills as those acquired skills that directly impact the academic performance of students in STEM careers. These include such skills as - critical thinking, analytical reasoning, quantitative literacy, study/time management skills, communication, and problem solving skills. A 10-point A*cademic Performance Impact (API) index* scale was developed to measure students perceived improvement in their *API*.

A framework for modeling the *API* index as a linear combination of *API* skills as variables is proposed and expected. The *API* index is shown to have a statistically significant impact on achievement gain. The Project was 65% effective in preparing high school students for college level math and science instructions, as well as enriching their Academic Improvement skills and ability to excel in their senior year of high school. The Project contributed to 80% educational growth and 35% academic performance improvement among those students who scored lowest on the pre-test compared to 25% improvement among those that scored highest in the pre-test. The Project was most effective in providing a pathway for increasing critical thinking, analytical reasoning and problem solving skills, educational growth, and preparing for the academic year. Self-confidence was shown to have the lowest impact (54%) for 9 and 10^{th} grade students who still appeared to be intimidated by math and science compared to 11 and 12^{th} grade students (67%).

Introduction

Research shows that barriers to access, matriculation, and retention vary among underrepresented groups with motivation, preparation, resources, emotional and social barriers, and fear of risk-taking and leadership[1-4] cited as the most common barriers. Studies sponsored by the National Science Foundation also show that although the preparation for college is improving for African Americans students, the percent of high school graduates who enroll in college has not increased due to deficiencies in quantitative literacy in K-12 curricula and the lack of activities that relate science, mathematics, engineering and technology (STEM) to real world experience.[1] The American Association for the Advancement of Science Project 2061 has noted that merely "covering" the topic or teaching unit is not sufficient to assure that the material will actually help students learn important ideas within those topics.[2] In contrast, Project CARE research from our institution and others clearly shows that being involved in problem-solving activities was an important achievement predictor for both white and African-American urban girls.[5] High school participants in Project CARE reported that the program was highly effective in impacting their communication skills (91.1%), analytical skills (93.3%) and interest in STEM careers (70%).[6-7] One approach known to nationally improve science literacy is to use hands-on science projects which allow students to make connections between abstract science and real-life situations and to use science to make decisions following defined standards. There is a need within the curriculum for a focus on how to effectively deliver the fundamental idea of the material to help the students learn and retain the core concept. The International Technology Education Association[8] and National Research Council[4] recommend that following a technology content standard with well-defined guiding principles can do this. The National Council of Teachers of Mathematics (NCTM)[8] has found that the K-12 curriculum is not giving all students solid preparation for work and the conceptual basis for further development. Based on these findings, NCTM recommends in its new Curriculum Reform Tool that the standard for teaching mathematics in the nation's K-12 schools should include activities for learning mathematics by actively building new knowledge from experience and prior knowledge.

The ability of students to extend learned mathematical and scientific concepts to other frontiers can be closely correlated to academic success in science and engineering. Hence, to ensure academic success in engineering, most engineering freshmen students at top national universities rank in the top 1-10% of their graduating high school class and/or have SAT scores above 1285. However, a standardized test such as SAT or ACT is not usually a true predictor of success for African and Hispanic American students, and without an adequate academic support environment, even a high SAT score does not guarantee academic success in science and engineering. As a national trend, bridge programs are often used to enhance the academic preparation of students falling below this standard. Unfortunately, some of these programs have proven to be insufficient in closing the achievement gap caused by the weak high school math and science backgrounds and the lack of critical and analytical thinking skills.

Project Goals and Objectives

Project CARE framework for design of activities that address these problems stems from the belief that remediation to better prepare students for science and engineering should begin earlier (in the middle and high school grades). Program design was based on four fundamental premises: (1) enrichment of the *Academic Performance Impact(API)* skills will minimize the barriers that hinder students' performance and attraction to STEM careers, (2) use of collaborative learning contribute to students' motivation and interest in STEM careers, (3) enrichment of API skills to prepare students for science and engineering should begin earlier, during the middle and high school grades, and (4) support services for these students must continue through at least college freshman year.

Project CARE was a comprehensive six-week, 10 hours/day, six days/week summer residential program activities with the aims to increase the achievement of 9-12 grade participants in general quantitative and science literacy skills, increase students' early awareness of engineering careers, provide informal experiences that promote an expectation for excellence and interest in STEM degree, prepare participants for the college level calculus and chemistry that is typical for engineering students, build competence in problem solving and technical communication by the end of 12^{th} grade, and motivate high school youth to follow their individual career interests in the STEM fields of interest [Ref]. This paper focuses on the following goals:

1. **Investigate best strategies and practices for enriching students' developing Academic Performance Impact skills and motivating students' interests in STEM.**

2. **Assess students' perceived improvement in *Academic Performance Impact (API)* skills and educational growth.**

3. **Develop a scaled model for measuring *Academic Performance Impact (API)* index and assessing math and science achievement gains of pre-college high school students.**

API skills are defined as those acquired skills that impact academic performance or preparedness for STEM careers. The average impact of those skills is measured by ***Academic Performance Impact (API)* index**, also defined as ***Academic Preparedness Index.*** Academic performance impact skills consist of primary (foundational) and secondary skills. A non-exhaustible list of these skills for STEM fields is shown in Table 1:

Table 1: Examples of STEM Academic Performance Impact skills and Measures

Academic Performance Impact (API) skills	STEM Preparation Measures (SPM)
Problem-Solving skills,	Interest in STEM
Quantitative reasoning skills,	Self-Confidence for STEM
Critical Thinking skills,	Motivation for STEM
Analytical-Reasoning skills,	Educational Growth for STEM
Computer Literacy skills,	Initial Preparation for STEM
Global Learning skills	Standardized Tests/GPA/Grades
Inter-Cultural Competency skills	Attraction to STEM
Study/Test-taking skills	Retention in STEM
Organizational skills	Competency/Proficiency Math
Social/Networking skills	

Communication skills Self-Leadership skills

Some of these skills may also apply in non-STEM fields, such as in medical, legal, and business careers, which in themselves may need other skills separate from or in addition to some of these.

The primary Academic Performance Impact skills are student's basic foundational acquired skills that support and impact high academic performance in STEM courses and can predict student preparation for STEM. The STEM Academic Preparation Measures result from the primary or foundation skills. For example, it is assumed that poor mathematics problem-solving skills can affect a student's interest, motivation, or self-confidence to consider STEM as a course of study in college. We predict a high degree of correlation between primary impact skills and preparation for STEM.

Project Design and Activities

Goal 1- Investigate best strategies and practices for developing Academic Performance Impact skills and increasing motivation of high school students for STEM careers.

Hypothesis 1.1: Integration of quantitative/math literacy and science literacy standards in early high school curriculum will enrich academic performance impact skills, math and science proficiencies, and educational growth and preparation for STEM career.

The approach used to test this hypothesis was to enhance academic preparation in college algebra, engineering learning tools, and technical writing/communication skills of high school students. Twenty (20) pre-11th (referred to as CARE 10) and twenty (15) pre-12th grade (referred to as CARE 11) students were selected across the nation with 60% of the students from the Pittsburgh area public schools. The objectives were for more than 50% of the participants to advance in mathematics, general quantitative and science literacy, basic writing and technical communication skills, as well as to increase early awareness of and interest in STEM education. For the pre-12 grade students, problem solving and critical thinking skills acquired in pre-11th grade year were integrated into college level pre-calculus/calculus and science courses as a foundation for an engineering education. The project targeted 9-12 grade students with over all a "B" average or better. Some advanced honor 9th grade students that have completed their 9th grade were selected and included as part of CARE 10 cohort. Because an overwhelming number of applicants had only general interests in STEM and not particularly in engineering, 25% of the cohort constitutes a subgroup with a weak interest or no interest in engineering. It was assumed that this subgroup would show motivation for engineering as a result of the project activities targeted for the purpose.

The project adopted the ITEA Standard for Mathematics and Technology Literacy; namely, students in 9-12th grade levels *will develop an understanding of core concepts of technology* [6]. This standard provided a common set of expectations for what students should learn and the basis for developing meaningful, relevant and articulated curricula with links to 9-12th grade curricula and engineering fields of study. Similarly, the learning objectives and activities in chemistry and physics incorporated ITEA standards to frame the building blocks of science literacy and function together to solve complex real-life problems with appropriate compromises.

In communicating with high school math and science teachers and school of engineering faculty that teach freshman and sophomore courses, it was determined that the majority of the freshman students experience the greatest difficulty in understanding trigonometry functions. In meeting mathematical and technology standards, the project design intentionally included selected courses and activities to provide a common set of expectations for what 9-12th grade students should learn and connect those expectations with an engineering field of study. Project CARE mathematics and technology learning objectives to reach this milestone are as follows:

Math Learning Objectives/Skills set for

- Define the six trigonometric functions using the lengths of the sides of a right triangle, and solve problems involving the periodic properties of trigonometric functions of a real variable.
- Generate graphs of trigonometric functions and their inverses, and explore transformations of these graphs, including applications to solving real world problems.
- Learn and apply fundamental identities and formulas of trigonometry and of angles and use them to simplify expressions or solve equations.
- Understand and apply the properties of vectors to solve a variety of problems.
- Be able to convert points and equations from polar to rectangular coordinates, and vice versa.
- Represent complex numbers in trigonometric form and perform operations on them.
- Solve systems of equations and inequalities algebraically, graphically, and using matrix operations, where appropriate.

The following introductory courses were designed to meet quantitative/Math literacy standard:

Foundational Mathematics I (Algebra 1 and 2, Problem Solving) – This course is a college level math course designed to help students solidify their basic mathematics skills and give them opportunities to develop the problem solving skills necessary to succeed in an engineering major. Problem Solving / Logic using algebraic formulations, inequalities, functions and graphs, word problems, puzzles and other informal hands-on-mathematics tools (such as a graphic calculator) are introduced to increase critical thinking skills and develop reasoning and logic in the problem solving skills necessary to succeed in engineering. The course was open to CARE 10 students and taught in a combination of lecture and technology-based cooperative learning in an interactive learning environment with emphasis on the relationship between the engineering and mathematics.

Foundational Mathematics II (Pre-Calculus, Critical thinking) –This was designed as an introduction to pre-calculus and a continuation of Foundational Mathematics I covering functions and graphs, trigonometry, identities/equations and analytical geometry and their integration into Calculus and engineering. The course emphasized problem solving/ Logic using functions and graphic calculator, word problems, puzzles and other non-traditional tools to increase critical thinking skills and develop reasoning and logic in the problem solving skills necessary to succeed in a STEM course during the freshman or sophomore year. The objectives were for the students to make solid improvement in critical thinking and preparation for the college level calculus, physics and chemistry that are typical for engineering students and to enrich their problem solving and technical verbal/writing communication skills**.**

Written communication /Reading I course was designed to enhance students' technical writing and engineering communication skills and to give them an opportunity to explore different writing techniques. Library reading is integrated with writing activities that promote competency in information gathering and organization skills, as well as critical thinking skills. The objective was for solid improvement in basic writing/reading and technical communication skills at the end of 11th grade.

Chemistry/Science Literacy Standards/Skills set include:

- **Problem solving**: Must be able to read and understand what a question or system is asking and learn how to apply their knowledge to understanding the functioning of a system and solve the problems connected to the working of the system.
- **Algebraic manipulation**: Must be able to use algebraic manipulations to solve math problems and show relationships between the variables in a system.
- **Critical thinking inquiry**: Must learn and be able to ask why and explain conceptually what is happening or the behavior of a system rather than only solve mathematically.
- **Application:** Must be able to discuss with other students a concept or application of chemistry in explaining the building blocks of technology and how these blocks are embedded within larger technological, social and environmental systems.
- **Inter-dependence of system components**: Must learn that the stability of the technological system is influenced by all of the components in the system and recognize the many different ways chemistry effects life.

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Hypothesis 1.2: Use of collaborative and inquiry-based learning will enrich academic impact skills of pre-11^{th} and pre-12^{th} grade cohort students.

Four project activities were used to test this hypothesis: teacher directed technology based collaborative learning strategies, design projects, research methods, and hands-on-science activities integrated into the following science and quantitative literacy and engineering tools courses*:*

- **Introduction to Engineering Science I – Chemistry.** This course was designed as an introduction to chemistry and its integration to engineering with an emphasis on problem solving and critical thinking skills. This course introduces measurements and classification of matter; atoms, molecules and ions as the building blocks of technology; equations and moles concepts; chemical reactions, and basic stoichiometry.
- **Engineering Tools I** was designed to use hands-on-engineering and scientific methods in a cooperative learning environment to explore analytical reasoning and interactively expose students to various math and science areas and their relations to engineering. Students were introduced to application of SOLIDWORKS to engineering design and problem solving.

- **Engineering Tools 11** (Continuation of Engineering Tools I**)**–This course employs hands-on-engineering with computers (with SOLIDWORKS and ANSYS design software) and graphic calculators, as wells as research-to-learn activities to explore independent reasoning in various math and science areas and their relationship to engineering.
- **Engineering Design/Research Projects** activity course was designed to include integration with other courses such as mathematics, research methods, chemistry and physics, learning-by-design using the SOLIDWORKS and MATHLAB software activities to expand students' critical thinking and understanding of the process of solving real-world problems. The technical writing/research projects were designed to introduce students to research steps involved in writing a technical report, procedures in formatting and preparing a written technical report, and the procedures in creating and presenting an oral technical report. The activities guided the students to discover the basic design, analytical, graphical, problem solving, teamwork and communication skills used by all engineers, including the use of the computers as an engineering problem solving tool.

These activities focused enriching and assess students' development of API skills (Quantitative reasoning skills, critical Thinking skills, Problem-Solving skills, Analytical reasoning skills, Computer Literacy skills, Competency skills, study/Exam taking skills) by integrating these into the courses to enrich API skills; improvements were measured by math and science pre- and post-test scores, GPA, class ranking, and 5-point Likert surveys

Goal 2: Assessment of students perceived improvement in *Academic Performance Impact (API)* skills and educational growth.

Hypothesis 2.1: The academic performance impact skills have significant impact on student test scores and educational growths.

A 10- point scale (API index) was designed to measure student's perceived improvement in the API or the degree to which participants felt the program contributed to their educational growth and performances in math and science. Eight of these APIs were measured using a 10-point scale instrument by asking the students to rate, on a scale of 0 (No) to 10 (High) improvements—how they improved in following:

- Problem-solving skills
- Quantitative skills
- Critical thinking skills
- Analytical skills
- Leadership skills
- Motivation for STEM
- Competence
- Study Skills

In another instrument, the students were asked using 5-point Likert scale[9] to rate how the API affected their academic growth and ability to do math and science, academic year and their likely grade or GPA.

Goal 3: Develop a scaled model for measuring *Academic Performance Impact (API)* index and assessing math and science achievement gains of pre-college high school students.

Hypothesis 3.1: Enrichment of API skills will increase preparation, educational growth and achievement gains in math and science.

To test this hypothesis, it was assumed that the overall or effective Academic Performance Impact Index API *(x)* is a linear function of the academic Performance Impact skills (API_s) measures, written as:

$$API_n(x) = \sum_{i=1}^{n} x_i \ APS_{si} \quad (2)$$

where x_i =contribution coefficient for *the* $_{APIsi}$ skill
$i=1, 2, 3 \ldots n$ and n= total number of impact skill*s*

Each academic performance impact skill contributes to a student's overall *API* index and achievement gain. *API* index can be used to predict student potential performance in STEM courses or career by predicting the student achievement gain, educational growth, and grade improvement.

The overall *API* skills is sum effects of the foundational primary academic performance skills (API_s) and the Associated STEM Academic Preparedness Indicators (SAPI)
Where,

Foundational Academic PerformanceImpact skills (API skills)

Ps = Problem-solving skills
Qs = Quantitative reasoning skills
Ct = Critical thinking skills
Ar = Analytical reasoning skills
Tc = Communication skills
Cl = Computer Literacy
St =Study/Test taking Skills

Associated STEM Academic Preparedness Indicatorss

Co = Competency/Proficiency Skills
Int = Interest in STEM
Sc = Self-Confidence for STEM
Mo = Motivation for STEM
Le = Leadership Skills

With each academic performance skills index known, the contribution coefficients can be determined by appropriate linear fitting procedure or by maximizing the function *API (x)* subject to appropriate constraints on the coefficients written as:

$$Maximize\ API(x): aPs + bQs + cCt + dAr + eTc + fInt + gSc + hMo + iLe = Max \quad (6)$$

Subject to: $a + b + c + d + e + f + g + h + i \leq 1$
Plus other constraints

With multiple variable objective function and one constraint equation, unique solution is obtained by appropriate number of constraint equations. For each group of student, the API can models as a power law non-linear fit to the API in the population.

$$API_i(x) = \sum_{i=1}^{N} x_i \ {API_{si}}^k \quad (2)$$

Where k is an exponent that depends on contribution of that skill to API, and N is the number of students in the population.

Project design and data collection

A five-point Likert-type item or Likert scale was used to evaluate respondents' levels of agreement to research statements. The Likert scale consist of a series of four or more Likert-type items that are combined into a single composite score/variable as a quantitative measure of a character or personality trait.[9] For this project, Likert-type items and analysis are used to individual items while Likert scale and analysis are used to determine API as a composite effect of academic performance. For the Likert scale to measure API, an interval scale is used. In this case, the data also used numbers to indicate order and relative distance between points on the scale.

The project is heavily data driven, from planning and implementation to completion. This paper presents the results of some of the surveys administered and summarized by an external evaluator on the final day of class to assess students' responses to different aspects of the program, the following assessments were made:

- *Weekly Reflection assessments*-Student survey to weekly perceptions through the six-week duration of the program. Survey responses from students and faculty were reviewed at the end of each week and provided data to guide any adjustment to program activities.
- *Key Program Impact and Performance*-5-point Likert Survey instrument was administered to the students to investigate the contribution of key program components such as hands-on science activity, collaborative/cooperative learning design, and courses, to educational growth and college aspirations; students were asked to indicate agreement or disagreement with the statements regarding the contribution of the component of the program to their API, educational growth and usefulness to a college.
- *API Improvement Survey*-A 10-point Survey instrument were administered to the students to investigate their perceived gain in academic performance skills and educational growth; students were asked to indicate in a scale of 0-10 their improvements in API.
- *Pre- and Post-tests*- Administered in each mathematics and science course to measure over all achievement gain and educational growth.
- *Student/Counselor Report*-Follow-up assessment of impact of the program on students' performance in the respective high schools ((after the student left the program).

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Each course incorporated specific activities designed to improve and assess students' development of the specific academic impact skills. In the survey items and during the weekly reflections, students were required to evaluate activity impact on their academic impact skills, instructors and class materials effectiveness in addressing those, appropriateness of pace of instruction, etc. The survey items asked about students' direct assessment of impact of each component of the program -components-technology-based collaborative leaning, hands-on science, engineering projects, assessment, teacher's effectiveness, etc. on specific AESs; other questions were included to uncover information about AESs such as motivation, initial preparation for STEM, educational growth, and overcoming obstacles. Weekly reflection quizzes and surveys tests were administered each week in addition to tests administered mid-program (three weeks) and final day of program. Open-ended items were included to give students the opportunity to explain answers, suggest improvements, and indicate what aspects of the program were helpful or not helpful.

Data Reduction and Analysis

Tables 1 and 2 show typical sample data summary responses of the participants to a specific research question to test a hypothesis. In this example, the students were asked to strongly agree (SA=1) to strongly disagree (SD=5) that the indicated program components contributed to their education growth.

Table : **CARE 10 (2005):** The class contributed to my educational growth

	N	Agreement	WLS	SA	A	NS	D	SD
Communication	20	70%	2.00	10	4	3	2	**1**
Physics	18	72%	1.94	8	5	3	2	**0**
Chemistry	2	100%	1.50	1	1	0	0	**0**
Trigonometry	7	86%	1.71	4	2	0	1	**0**
Pre-Calculus	4	100%	1.00	4	0	0	0	**0**
College Algebra	9	89%	1.67	5	3	0	1	**0**
Eng. Proj. - Bioengineering	10	90%	2.00	3	6	0	0	**1**
Eng. Proj. - Chemical	10	90%	1.60	5	4	1	0	**0**
Eng. Proj. - Industrial	5	100%	1.60	2	3	0	0	**0**
Eng. Proj. - Mechanical	16	69%	2.19	6	5	2	2	**1**
Logic/Problem Solving	18	67%	2.28	9	3	1	2	**3**
Engineering Seminar	20	75%	2.05	6	9	4	0	**1**
SAT - Math	20	80%	1.85	13	3	1	0	**3**
SAT - Verbal	20	85%	1.50	13	4	3	0	**0**

NS=Not Sure

Table 2: CARE 11 (2005): The class contributed to my educational growth

	n	Agreement	WLS	SA	A	NS	D	SD
Communication	22	68%	2.09	8	7	5	1	**1**
Physics	2	50%	2.50	1	0	0	1	**0**
Chemistry	20	85%	1.70	10	7	2	1	**0**
Trigonometry	5	80%	1.80	2	2	1	0	**0**
Pre-Calculus	8	88%	1.38	6	1	1	0	**0**
College Algebra	9	89%	1.33	7	1	1	0	**0**

Eng. Proj. - Bioengineering	10	70%	2.00	4	3	2	1	**0**
Eng. Proj. - Chemical	11	45%	2.45	3	2	4	2	**0**
Eng. Proj. - Industrial	14	79%	1.86	5	6	3	0	**0**
Eng. Proj. - Mechanical	7	86%	2.00	2	4	0	1	**0**
Logic/Problem Solving	NA	NA	NA	NA	NA	NA	NA	**NA**
Engineering Seminar	7	86%	1.86	2	4	1	0	**0**
SAT - Math	19	53%	2.58	5	5	5	1	**3**
SAT - Verbal	20	70%	2.15	8	6	3	1	**2**

The Likert scale averages in column 4 are determined as:

$$WLS = \frac{\sum_j^M jR_j}{n} \quad (1)$$

Where, $j= 1, 2,..M=5$, for five-point scale
R_j =Frequency Response for j^{th} scale,
WLS= Weighted Likert Scale average
n =Number of respondents

Descriptive statistics included the mean for central tendency, standard deviations for variability, the Pearson's r, *F*-test, ANOVA, and regression procedures for interval scale .[11]

Results and Evaluations

Impact of key program components on *Academic Performance Impact (API)* skills

Hypothesis: The academic enrichment skills have significant impact on *Academic Performance Impact (API)* skills

Figure 1 shows the effects of program on improving several of the academic performance skills. While less than 45% of the students agreed that their preparations for STEM were weak, the program had significant impact on all academic performance skills. While the majority of participants (82%) felt that hands-on experiences helped their understanding of lecture material, there were few (15%) that indicated ‘not sure’ as their response.

Most (59%) of the participants felt that the program helped them understand math better, but the proportion who thought the collaborative learning strategies helped them understand science better was higher (67%). Slightly more than two-thirds (69%) of participants felt that hands-on experiences helped their understanding of lecture material; the proportions were similar across both programs.

Half (50%) of the participants said the program helped them feel good when solving math or science problems. However, 33% were not sure, and one-fifth (20%) in the CARE 10 group disagreed.

A large majority (72%) said that the program reinforced their problem-solving skills; however, 27% in the CARE11 group were “not sure”.

- *Problem solving and math Proficiency skills*- a large majority (78%) said that the program critical thinking activities and use of technology did reinforce their problem-solving skills and proficiency in solving complex math problems. However, 27% in the CARE 11 group were "not sure."
- *Critical thinking skills*: the results show use of Hands-on science enriched critical and analytical thinking skills of 80% and 75% for CARE 11 and 10 groups, respectively, and helped the students understand and complete their math and science tasks.
- *Analytical Reasoning*- learning by-design activities improved analytical reasoning of over 65% of the students compared to 66% using STEM research projects with faculty. Design projects helped 67% of students explore their potentials (with 61% and 71% for CARE 10 and CARE 11, respectively).The agreement is probably higher one the over 30% students were "not sure" or disagreed. CARE 10 students who took Logic/Problem Solving course agreed with the statement by 75%.
- *Educational Growth*-A large majority (77%) of the respondents agreed that the program contributed to their educational growth; however, 27% of the CARE 11 participants were "not sure."
- More than a quarter (75%) of the respondents agreed that using a graphical calculator enhanced their proficiency and understanding of math.
- Most (78%) of the participants said that summer projects helped them understand engineering concepts.

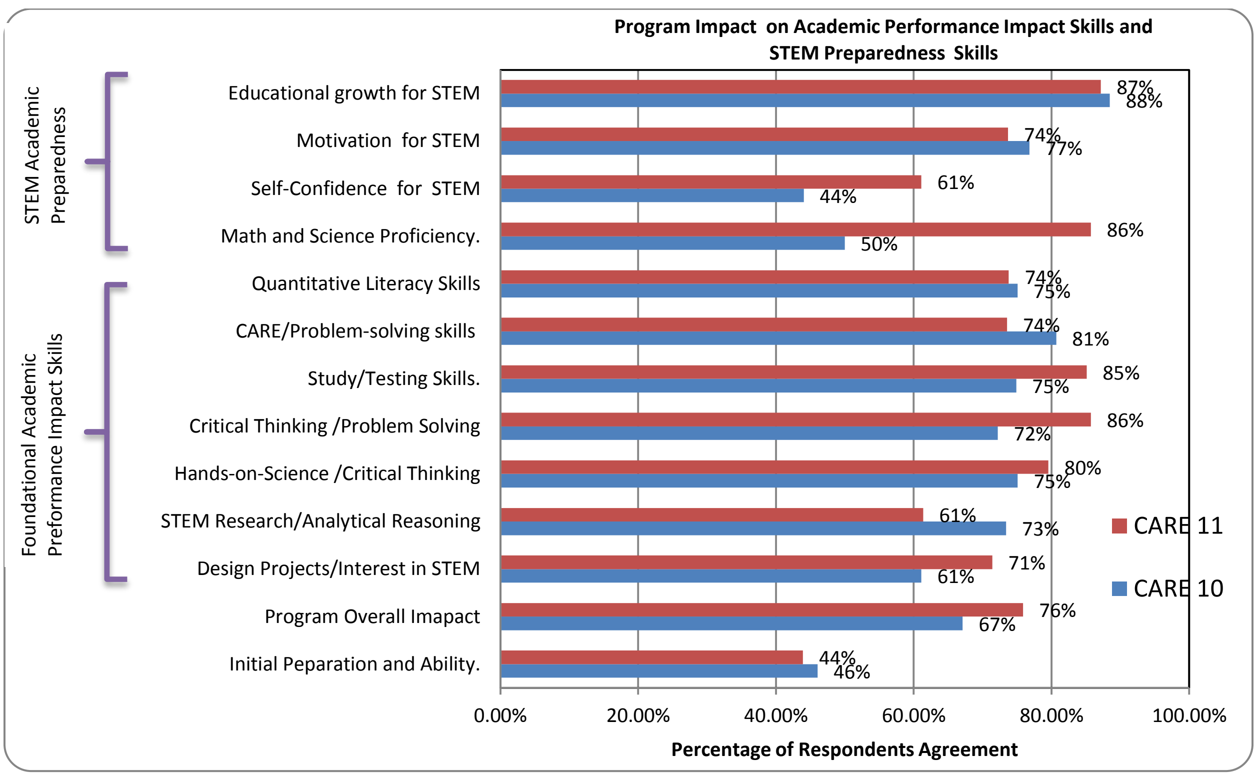


Figure 1: CARE students' level of agreement to impact on academic performance impact skills and STEM preparedness.

A large majority agreed that the program reinforced their problem-solving skills. Figure 2 shows that 100% of CARE 10 students agreed that Logic/Problem-Solving Skills will contribute to their educational growth and be useful for their college career (94%) while 89% agreed that engineering tools will contribute to their educational growth. Although only 50% of the students agreed that the pace of instruction was appropriate, they agreed that concepts learned in college algebra contributed to their educational growth (83%) and would be useful in their college career (94%). Students also see communication skills to be important in educational growth (61%) and college career (83%).

Similarly, In Figure 3 shows that assessment of CARE 11 students of the impact of Chemistry, engineering tools and pre-calculus on quantitative and technology literacy, and study and communication skills in improving learning. Almost all the participants (93%) agreed that chemistry and the associated lab contributed to their educational growth and will be useful for their college career (100%) while 79% agreed that engineering tools contributed to their educational growth. Although 43% agreed that the pace of instruction in pre-calculus was appropriate (67% indicated the pace was too fast), 86% agreed that the knowledge acquired contributed to their educational growth. Study and communication skills received the highest marks as the critical in sustaining education growth.

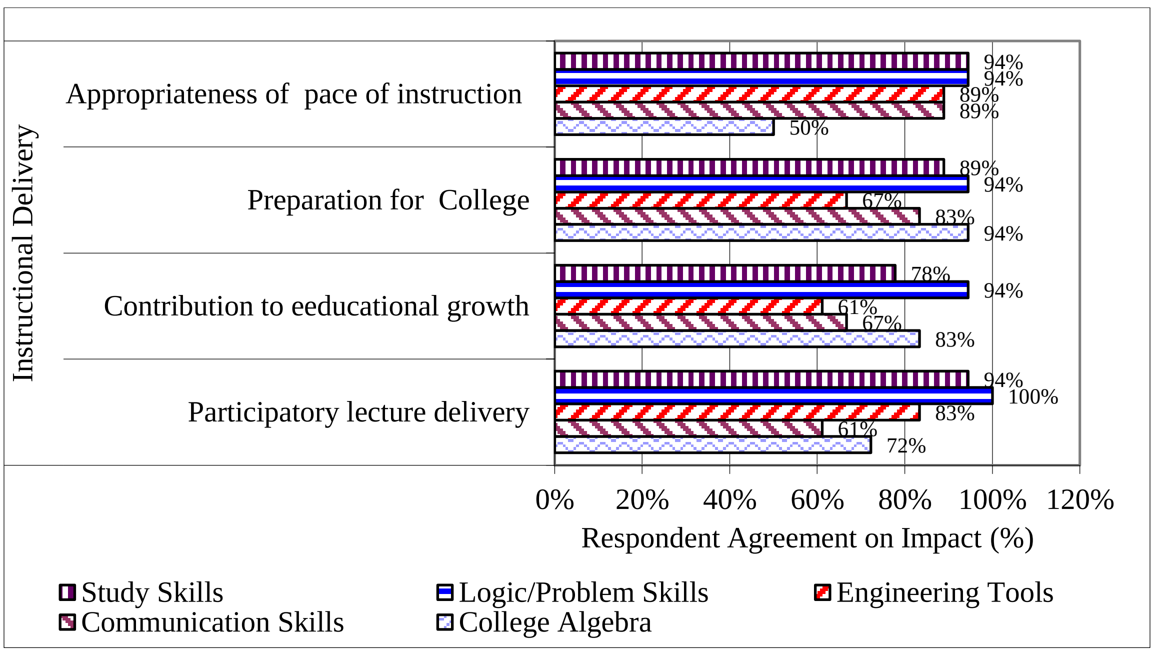


Figure 2 CARE 10 Respondents Agreement on Impact

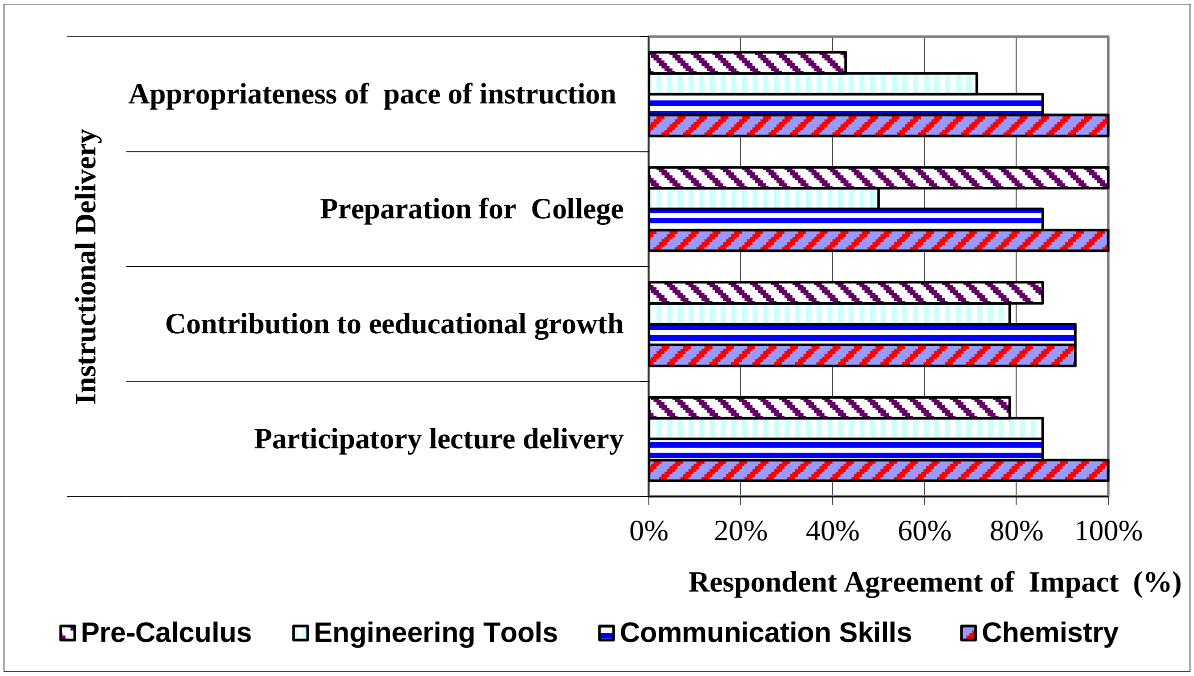


Figure 3. CARE 11 Respondents Agreement on Impact.

Impact on educational growth. Overall, a strong majority (94%) said that the program contributed to their educational growth. In another research question, the students were asked to rate how the impact factors affected their academic growth and ability to do math and science, academic year and their likely grade or GPA in the academic year following the summer program.

Table 3 is presentation of the Likert response data showing CARE 10 and 11 groups distinguished and the responses as whole (total) and shows the degree to which the participants felt the program contributed to their educational growth. More than three-fifths (77%) of the participants indicated either ‘Strongly Agree’ or ‘Agree’ to the statement.

Table 3: Participation in the program has contributed to my educational growth

	CARE 10 (n=20)	**CARE 11** (n=22)	**Total** (n=42)
Strongly agree	45%	50%	48%
Agree	35%	23%	29%
Not sure	10%	27%	19%
Disagree	5%	-	2%
Strongly disagree	5%	-	2%
Total	100%	100%	100%

Assessment of Preparation

Assessment of initial difficulties experienced by students entering the Project CARE program was done to estimate their preparation as a baseline for enrichment. Most of the students (80%) agreed that they had at least ‘a few’ problems and this proportion were nearly equal across all groups and program components. The 36 respondents who answered ‘yes’ to having initial difficulties were asked whether the Project CARE program helped them overcome these initial problems. Most (64%) said ‘yes’, including majorities in each of the programs. The results show that CARE 10 and 11 students’ experienced initial difficulties in two areas: *understanding the material* (12 responses) and *developing skills* (7 responses). Of the 12 who experienced understanding problems, 8 (67%) found help but 4 (33% in the CARE 10) did not. The 7 who needed help with skills were able to find the help they needed. In contrast to CARE 10, the CARE 11 students (7) were able to learn to overcome ‘organization’ problems. These were related to managing the logistics of the program such as managing the intensity and complex structure of the program.

Respondents were asked a follow-up question: those who answered ‘yes’ to the question above were asked how the program was helpful, while those who answered ‘no’ were asked why the program was not helpful. The responses to these questions are grouped by theme and program and displayed in Table 4

Table 4. Summary of follow-up to how and what the program helped

Yes, program has helped:

Theme	CARE Group	Number of Comments	Comment
Understanding	I	5	Things that I found to be difficult were explained. By pushing me to understand concepts at a faster pace. It helped me understand math concepts better. The program gave me an idea of pre-calculus. I’ve started to understand more math situations that weren’t understood before.
	11	3	Understanding lectures. I’ve learned to ask the questions I need answered. There were thorough explanations.
Organization	I	1	Life is difficult; classes in college are going to be rigorous so I’m better off dealing with it now.
	11	3	Learning to manage my time helped. It taught me how important it is to manage my time and study to get ahead and actually learn the material. I never rode the bus before and was never active in either an urban or college setting.
Skills	I	3	It helped me review problems in math that I didn't know how to do. It helped me build better skills in math. The math program was a little hard but the class helped me out quite a bit.

Theme	CARE Group	Number of Comments	Comment
	11	4	Study skills class improved my habits. Study Skills has helped me to overcome the stress of studying. It helped me mostly on my skills in math. By helping me in improving my study skills.
Tutors and Support	I	1	By having the tutor or other students explain the work to me.
	11	1	By finding ways of tutoring.

No, did not help

Theme	CARE Group	Number of Comments	Comment
Assignments	I	1	Because they still gave us more work.
Understanding	I	4	Not enough information or help with the topic.
			It just reviewed what I had already known and nothing helped me except SAT Prep & Problem Solving
			Because I still do not understand what I am doing.
			I don't really understand greatly, I need more detail.

Interest and Motivation for engineering:
To assess motivation for engineering career, students were asked if Project CARE helped reinforce their decision for a career in engineering and motivation for engineering. The results of this question revealed that most participants in the program were not further motivated for engineering by their summer program participation. The presence of the subgroup that did not have initial interest in engineering affected the overall responses. The table below shows that the effect of the 8 (25%) non-engineers' responses was mostly positive. This group perceived the program as increasing their educational growth but remained less motivated for or interested in engineering. In the selected questions shown below, those who had no initial interest in engineering responded more positively than the others to nearly all questions, except the questions that directly addressed motivation for engineering. The open-ended follow-up responses shed some light on this finding. In the displays below, these responses are grouped by comment theme and by program, starting with the affirmative responses and followed by the negative responses.

The 'Yes' responses were categorized into three groups:

- *Getting there* (14% (2/14) 11, 33% (6/18) I) – this group (47%) of respondents expressed some awareness and interest in the field, and given continued exposure, are most likely to consider engineering as a career.

- *Prepared* – 9% (3/32) respondents felt that the program provided a good preparation for entering the field.

- *This is for me* 16% (5/32) of the participants were definite and who have made up their minds that engineering is what they want.

The 'no' responses fell mostly into two categories:

- *Not feeling it*- 44% (8/18) of participants in the I program and 7% (1/14) in 11 felt that they did not fully experience what engineering is all about, or felt a bit intimidated by the science and math involved. These were categorized as 'not feeling it'. The group is still open to engineering but still looking for the right catalyst to inspire their interest. 66% of I students are likely to choose engineering as a career option.
- *Not for me* -In the 11 program, 57% (8/14) of participants indicated that they were not interested in engineering or were interested in other pursuits. Their responses were categorized as 'not for me'. Only 43% of 11 are likely to choose engineering as a career.
- It is clear that the year one activities did not make significant impact in motivating the pilot subgroup (who viewed their career aspirations as something other than engineering) to consider engineering as a career. This subgroup was strongly decided against engineering and their responses caused some negative responses to questions asking how the PECAP program motivated them to pursue engineering. The questions were framed with the assumption that the students had some initial interest toward engineering when in fact the students had original interest in science and medicine, and the program strategy was to motivate them to engineering. However, in examining the participants' ratings of several aspects common to, including the benefits of the STEM component and overall quality of the program on a 10-point scale (normalized to 100%), the program was 68% effective in impacting the participants' interests in STEM fields. As to the overall quality of the program, most participants (72%) rated it as excellent or 'very good'.

Table 5. Motivation for engineering

Yes, it motivated me

Theme	Group	Number of Comments	Comment
Getting there	I	6	It got me more interested and more aware about engineering. It showed me some programs engineers used. Makes engineering even more interesting. But only in certain fields. Sort of, I see how the career I want can be linked to engineering. It showed me how to combine my interest in math & science to explore Bioengineering. It helped me increase my interest in considering a career in the technical field.

Theme	Group	Number of Comments	Comment
	11	2	It involved a lot of skills that engineers may use in everyday life. I have been able to see practical uses for math and science.
Prepared	I	2	They showed what it really takes to be an engineer. I learned what it takes to be an engineer. It's hard but it's worth it.
	11	1	I've been more exposed to engineering aspects.
This is for me	11 11	1 4	Before I started the program, I was positive I wanted to be a doctor. Now I think I would like to be a biomedical engineer.

No, it did not motivate me

Theme	Group	Number of Comments	Comment
Not feeling it yet	I	8	Because I have learned nothing new. Because if engineering is all about science & math yet my skills are not up to the level they should be. Having a career in engineering stress me out. We did not do much with engineering. I don't feel I know enough about the field and what options it has. It didn't spend enough time talking about engineering. The field trips we went on have shown me how boring being an engineer can be. We were mainly doing math problem solving communication skills, we did not have many chance to truly experience engineering (probably there should be a computer course). It involves a lot of math.
	11	1	I'm still not sure what tasks an engineer performs.
Not for me	I	1	I do not wish to be an engineer.
	11	8	I am not interested in engineering major. I'm not really sure. Because I didn't exactly want to be an engineer. I'm more interested in medicine. I don't want to do engineering in the first place. I don't think engineering is a right job for me. I am not intending to study engineering. My goal is not to become an engineer. Engineering does not interest me.

Goal 3: Quantify the effect of *Academic Performance Impact (API)* skills on math and Science achievement gains of pre-college high school students.

Hypothesis: The academic enrichment skills have a combined significant effect on the students API and achievement gain. We also seek to understand whether there is a statistically significant difference between the API of CARE 10 and CARE 11 populations and pre- and post-test results, assuming no other significant interacting difference between students in each population.

To test this hypothesis, an Analysis of Variance (ANOVA) was used. We sought to find whether CARE 10 and CARE 11 had significantly different levels of test scores diversity or is there truly a difference in means across CARE 10 and CARE 11 groups.

Table 6: (displayed on Figure 2), shows the average API index for each cohort (CARE 10, CARE 11, and CARE (10 and 11 combined) on a 10-point performance improvement scale.

Table 6: Academic Performance Impact skills Index

	CARE 10 Pre-11th Grade	**CARE 11 (Pre-12th Grade**	**CARE (Total)**			
Critical thinking skills	7.6	7.9	7.8			
Problem solving skills	7.3	7.4	7.4			
Analytical Reasoning Skills	7.1	7.3	7.2			
Quantitative Literacy Skills	7.0	5.9	6.5			
Competence in SEM	7.1	7.2	7.2			
Motivation for STEM	7.6	7.2	7.4			
Interest in SEM	6.5	7.1	6.8			
Leadership Skills	6.4	6.8	6.6			
Self confidence	5.4	6.7	6.1			
Descriptive Statistics						
Mean	6.9	7.1	7			
Standard Error	0.2	0.2	0.2			
Median	7.1	7.2	7.2			
Mode	7.6	7.2	7.4			
Standard Deviation	0.7	0.6	0.5			
Sample Variance	0.5	0.3	0.3			
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
API skills	4.61	8	0.58	2.65	0.095	3.44
CARE Groups	0.13	1	0.13	0.583	0.47	5.32
Error	1.74	8	0.22			
Total	6.476111	17				

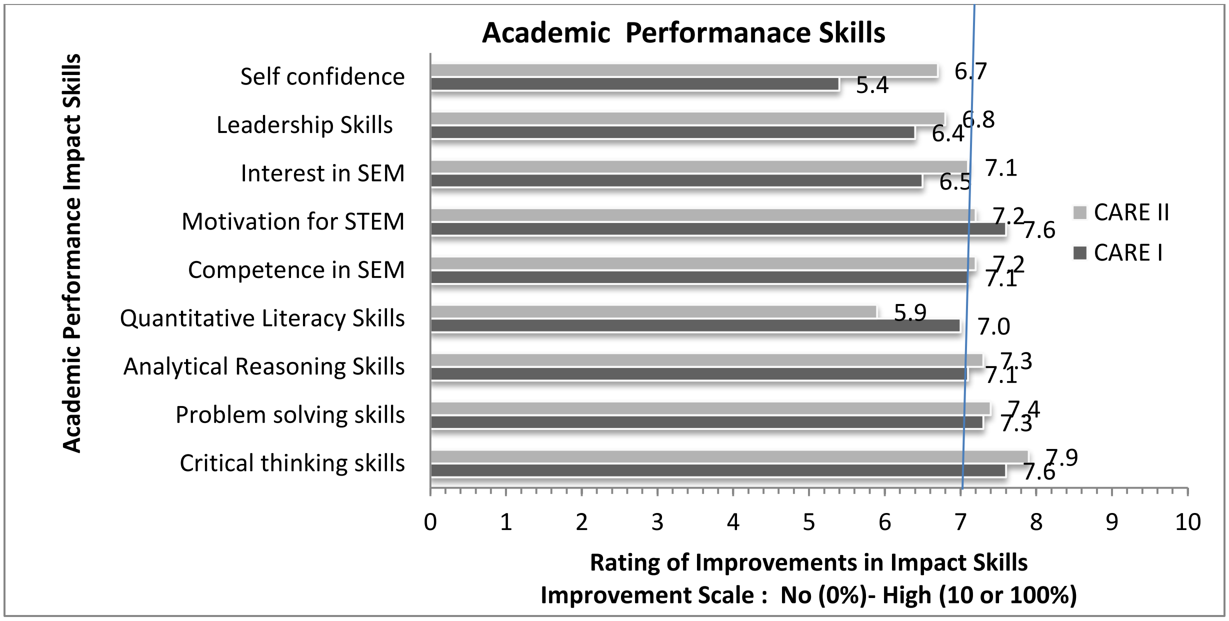


Figure 4. CARE 10 (Pre- 11th) and CARE 11 (pre-12th) grade student's perceived improvement in API.

For the three-year program period, the combined (CARE 10 and 11) mean value was 7.0 ±0.20 with a modal value of 7.4±0.20. The number of high average scores (those above 7.0) were in the areas of analytical skills, critical thinking skills, quantitative literacy, and problem-solving Skills. This shows that although the program had 7.4/10 perceived improvement in their primary academic preparation skills (analytical, critical thinking, quantitative literacy, and problem-solving), they felt slightly less (6.8/10) improvement in their secondary APS (self -confidence, leadership, interest, motivation, and competence). However, they perceived 7.4/10 in their motivation for STEM. Though the students in the open-ended questions indicated less motivation their perceived motivation in the API index appear to be high (7.3/10). Self-confidence received the lowest improvement, especially for CARE 10 students (5.4/10) who still appear to be intimidated by math and science compared to CARE 11 students (6.7/10).

The API rating schemes in Table 6 above carry a risk of being affected greatly by extreme values. In this instance, there were a number of students who provided zero (0) ratings in response to some items. Collapsing the ratings into categories—or clusters, as shown below—reduces the effect of extreme values. The Table 7 shows that each aspect received between 50% and 64% of its rating scores in the range of 7 to 10.

However, the scores differed greatly depending on whether the respondents were in CARE 10 or CARE 11 group. For every aspects, the proportion of scores in the 7-10 was significantly higher among the CARE 10 respondents (between 60% and 70%) than among the CARE 11 respondents (41% to 59%). Higher API index for CARE 10 means that this group perceived increased improvements in their academic preparation skills than CARE 11 students.

Despite the fact that CARE 11 students tended to rate the benefits of the program lower than the CARE 10 participants, they were more likely to rate the overall quality of the program higher. As shown in Table 8 below, 68% of the CARE 11 participants gave the program ‘excellent’ or ‘good’ ratings, compared to 53% of the CARE 10 participants. The reason for this was not clear from the data although the weekly reflection data show that the CARE 10 group were the more likely to complain about the intensity of the program and not enough time for fun than the CARE 11 students.

Table 7. API Index Cluster

		API index Cluster (0-10)			
Aspect	**Program**	**0 - 3**	**4 – 6**	**7 - 10**	Total
Analytical skills	10	10%	30%	***60%***	**100%**
	11	32%	23%	45%	**100%**
	TOTAL	21%	26%	52%	**100%**
Critical thinking skills	10	15%	25%	***60%***	**100%**
	11	14%	45%	41%	**100%**
	TOTAL	14%	36%	50%	**100%**
Interest in SEM	10	15%	15%	***70%***	**100%**
	11	18%	27%	55%	**100%**
	TOTAL	17%	21%	62%	**100%**
Problem solving	10	10%	25%	***65%***	**100%**
	11	23%	32%	45%	**100%**
	TOTAL	17%	29%	55%	**100%**
Quantitative skills	10	10%	20%	***70%***	**100%**
	11	9%	32%	59%	**100%**
		10%	26%	64%	**100%**
Self confidence	10	15%	25%	***60%***	**100%**
	11	27%	27%	45%	**100%**
	TOTAL	21%	26%	52%	**100%**

Table 8: How do you rate the overall quality of the CARE program?

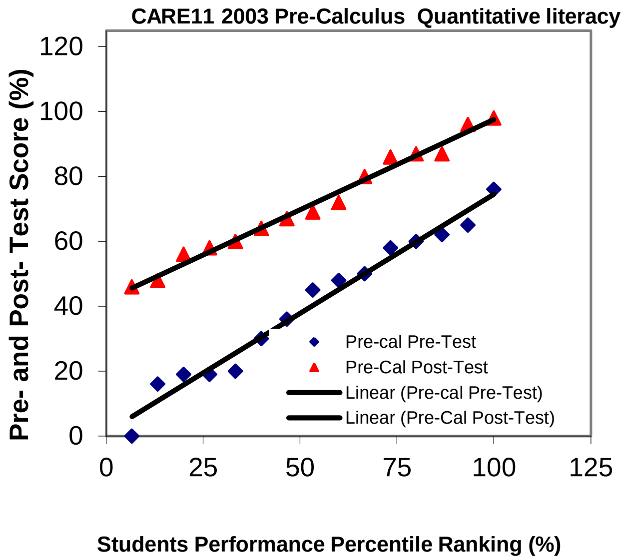
	Percent Effectiveness		
Rating	**Total**	**CARE 10**	**CARE 11**
Excellent/Good	61%	53%	68%
Excellent	22%	21%	23%
Good	39%	32%	45%
Average	32%	32%	32%
Below Average	5%	11%	0%
Poor	2%	5%	0%

Impact on pre-and post-test results

Figures 5 to 7 show a linear dependence of math and science post-test scores on students' performance percentile ranking. Academic growth of the participants is measured in terms of achievement gains on pre-and post-tests. The pre-test was based on content of the learning objectives while the post-tests tested the same concepts but at the mastery level, including the use of technology. Comparison of the unranked pre-calculus pre-and post-test results shows that 15 out of 16 students made significant improvements in mastering the subject matter. There was a moderate difference in improvement (11% higher) for students who scored highest in the pre-test compared to the 48% difference in improvement for those that scored lowest in the pre-test. This may be attributed to "over-confidence factor" of this student group at the beginning. In science, 16 out of 16 students made improvements from the pre-test to the post-test. This was also observed in 10^{th} grade college Algebra results which showed that 16 out of 16 students made improvements from the pre-test to the post-test. The most dramatic change was from a 12% to a 96% (84%) and from a 0% to a 79% score (79%). Achievement gain increased linearly with percentile ranking.

Table 9: Descriptive statistics for pre and post test data

	Pre-Test %	Post-Test %	**Pre-Test**	**Post-est**		
Statistics		2004		2005		
Mean	29.2	71.6	18.5	88.58		
Standard Error	5.7	5.1	3.63	2.63		
Median	29.0	75.0	18.5	89.5		
Mode	0.0	56.0	24	#N/A		
Standard Deviation	24.2	21.7	11.47	9.10		
ANOVA	**2004 Pre-Test %**	**Post-Test %**	**Pre-Test**	**Post-test**		
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Students	14912.47	17	877.20	6.61	0.00016	**2.27**
Pre- and Post-Tests	15334.69	1	15334.69	115.56	~0	**4.45**
Error	2255.81	17	132.69			
Total	32502.97	35				
ANOVA	**2005 Pre-Test %**	**Post-Test %**	Pre-Test	Post-Test		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	***F crit***
Students	2087.45	11	189.77	5.44	0.0046	**2.82**
Pre- and Post-Tests	27405.04	1	27405.04	786.15	~0	**4.84**
Error	383.46	11	34.85			
Total	29875.96	23				



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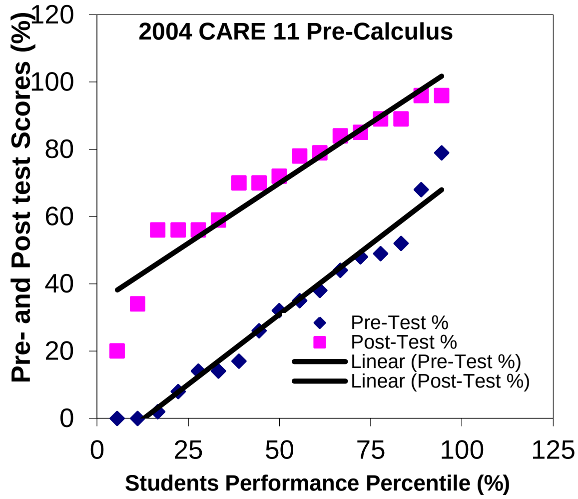

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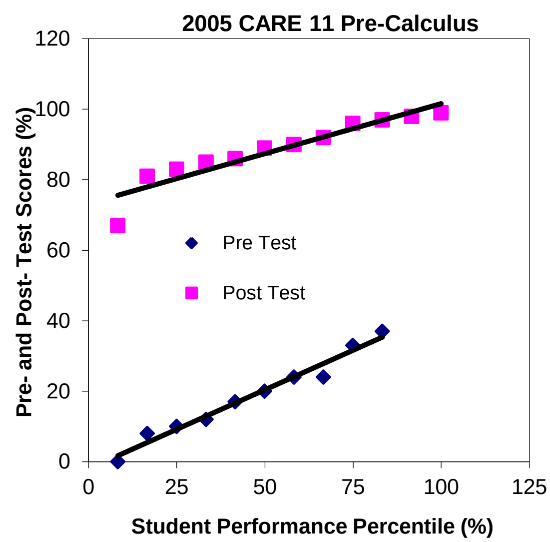
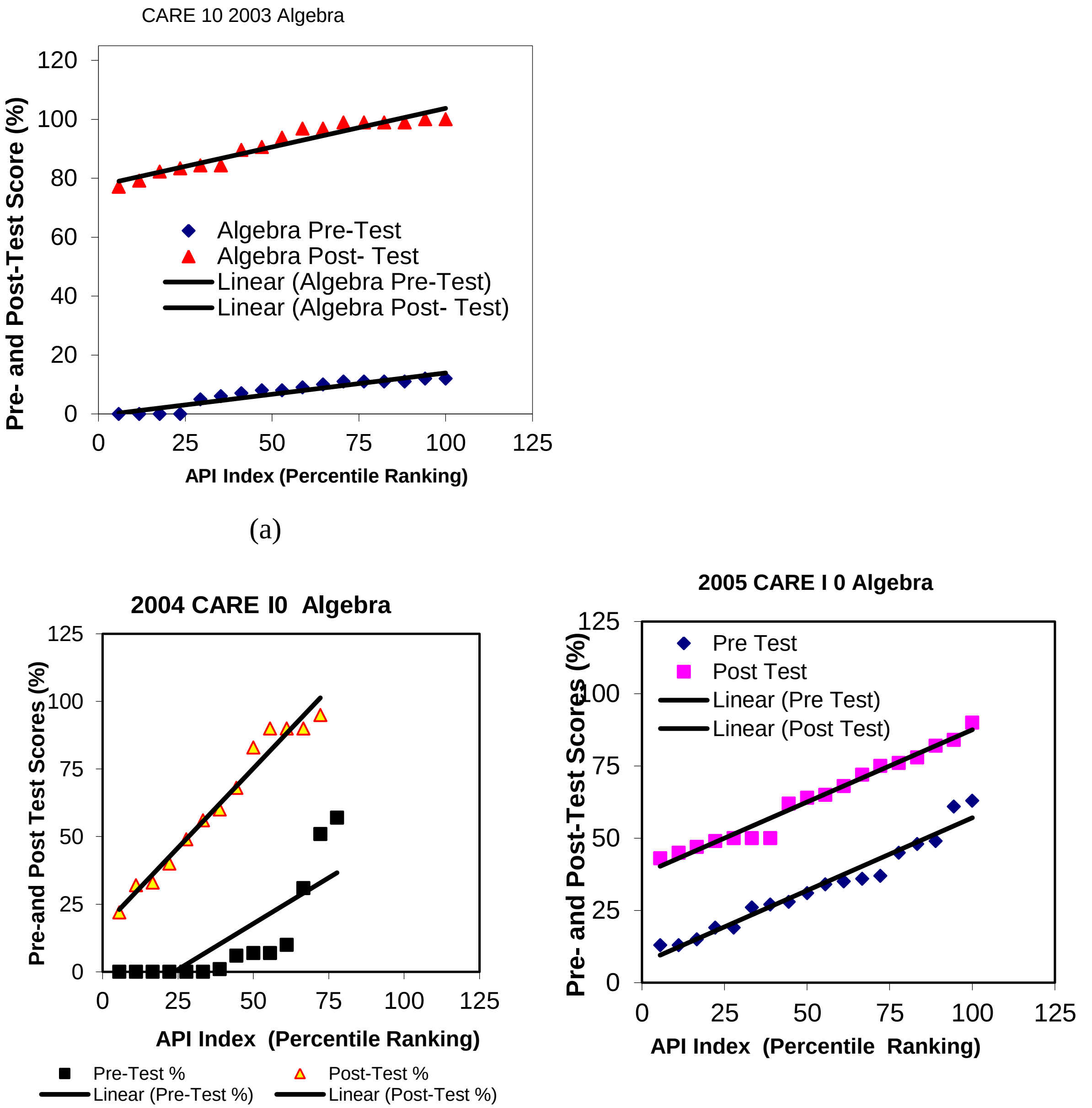


(c)

Figure 5. Assessment of quantitative literacy based on performance in pre-calculus for pre-and post-tests for pre-12th grade CARE 11 students for (a) 2003, (b) 2004, and (c) 2005.



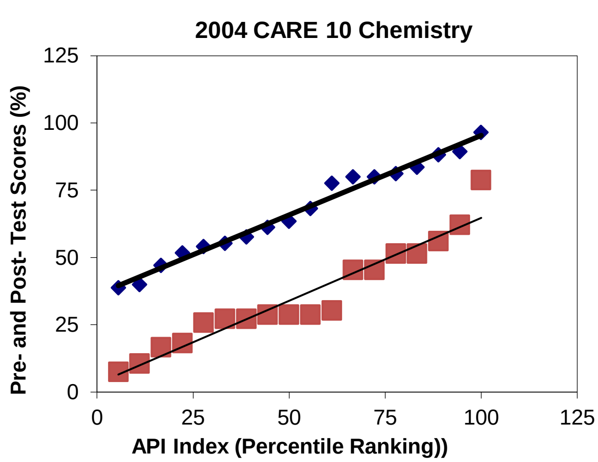
(a)

(b) **(c)**

Figure 6. Assessment of quantitative literacy based on performance in Algebra for CARE 10 students for (a) 2003 (b) 2004, and (c) 2005

Table 10: CARE 10 Pre and Posttest Algebra Statistics

	Pre-Test %	Post-Test %	Pre-Test %	Post-Test %		
	2004		**2005**			
Mean	12.1	58.4	33.3	63.9		
Standard Error	5.2	7.6	3.6	3.5		
Median	3.5	58.0	32.5	64.5		
Mode	0.0	90.0	13	50		
Standard Deviation	19.6	28.5	15.27707	15.04851		
ANOVA 2004 Algebra						
Source of Variation	SS	Df	MS	F	P-value	**F crit**
Rows	12598.75	13	969.1346	4.258955	0.006869	**2.576927**
Columns	14950.32	1	14950.32	65.70062	1.94E-06	**4.667193**
Error	2958.179	13	227.5522			
Total	30507.25	27				
ANOVA 2005 Algebra						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	***F crit***
Rows	6981.25	17	410.6618	8.34939	3.3E-05	**2.271893**
Columns	8433.361	1	8433.361	171.4633	2.62E-10	**4.451322**
Error	836.1389	17	49.18464			
Total	16250.75	35				



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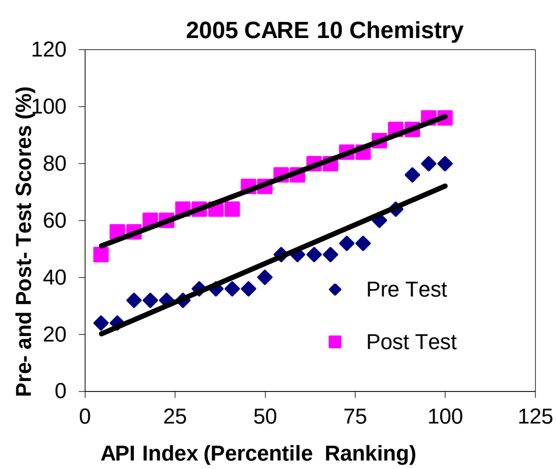

(b)

Figure 7. Comparison of assessment of science literacy based on performance in chemistry for CARE 10 students for (a) 2004 and (b) 2005.

Table 11:

Chemistry CARE 10	Statistics	2004		2005	
		Pre Test	Post Test	*Pre-Test*	***Post-Test***
	Mean	46.18	73.82	35.60	**67.50**
	Standard Error	3.61	3.02	4.5	**4.2**
	Median	44	74	28.8	**65.9**
	Mode	32	64	28.8	**80.0**
	Standard Deviation	16.913326	14.1678253	19.0	**17.7**

ANOVA 2004 CARE 10 Chemistry (Science Literacy)

Source of Variation	*SS*	*Df*	*MS*	*F*	***P-value***	***F crit***
CARE 10 Group	8646.80	17	508.66	3.04	**0.014**	**2.27**
Pre & Post Test scores	9126.94	1	9126.94	54.43	**1.08E-06**	**4.45**
Error	2850.44	17	167.67			

ANOVA 2005 CARE 10 Chemistry (Science Literacy)

Source of Variation	*SS*	*Df*	*MS*	*F*	***P-value***	***F crit***
CARE 10 Group	8608	21	409.90	5.33	**0.00016**	**2.08**
Pre & Post Test scores	8401.45	1	8401.45	109.28	**8.86E-10**	**4.32**
Error	1614.55	21	76.88			

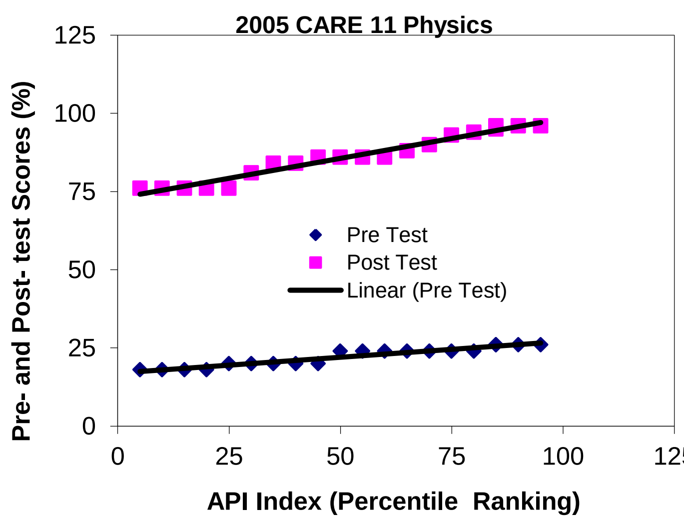

Figure 8. Assessment of science literacy based on performance in Physics for CARE 11 students

Table 12: **Science literacy based on performance in Physics for CARE 11 students**

	2005 CARE 11 Physics						
	Pre-test	Post test					
Mean	22.2	86.05					
Standard Error	0.679009	1.659859					
Median	24	86					
Mode	24	76					
Standard Deviation	3.036619	7.423115					
ANOVA Physics							
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	***F crit***	
Rows	1006.875	19	52.99342	4.677157	0.00075	**2.168252**	
Columns	40768.23	1	40768.23	3598.171	4E-23	**4.38075**	
Error	215.275	19	11.33026				
Total	41990.38	39					

Table 13: **Academic Performance Impact skill indices for CARE 10 and CARE 11 student groups**

	Academic Performance Impact skills Index					
	CARE 10 Pre-11th Grade	**CARE 11 (Pre-12th Grade**	**CARE (Total)**			
Critical thinking skills	7.6	7.9	7.8			
Problem solving skills	7.3	7.4	7.4			
Analytical Reasoning Skills	7.1	7.3	7.2			
Quantitative Literacy Skills	7.0	5.9	6.5			
Competence in SEM	7.1	7.2	7.2			
Motivation for STEM	7.6	7.2	7.4			
Interest in SEM	6.5	7.1	6.8			
Leadership Skills	6.4	6.8	6.6			
Self confidence	5.4	6.7	6.1			
Descriptive Statistics						
Mean	6.9	7.1	7			
Standard Error	0.2	0.2	0.2			
Median	7.1	7.2	7.2			
Mode	7.6	7.2	7.4			
Standard Deviation	0.7	0.6	0.5			
Sample Variance	0.5	0.3	0.3			
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
API skills	4.61	8	0.58	2.65	0.095	3.44
CARE Groups	0.13	1	0.13	0.583	0.47	5.32
Error	1.74	8	0.22			
Total	6.476111	17				

Tables 9 to 12 show *F*-test statistic from the ANOVA using an α of .05 show that the *F*-test statistic in all cases was much greater than the critical value for CARE 10 and CARE 11 groups. Hence, there is a statistically significant difference in the population means of pre - and post-test scores in the two respective years reported (2004 and 2005) for algebra p< (0.0069 and .000033), pre-calculus p< (0.00016, and 0.00450), chemistry (p< (0.014 and 0.000160), and physics ($p < 0.00075$) for 2005. The pre and post-tests from student to student were also statistically significantly different with $p < 0.05$ in all cases.

For table 13, the *F*-test statistic is less than the critical value with *p*-value of ($p > 0.05$). Hence, in this case we accept the null hypothesis of equal means for the CARE 10 and CARE 11 groups and conclude that there was no statistically significant difference among the population means, that is, a statistically no significant difference between API mean values for CARE 10 and CARE 11 students. There is also no significant difference from student to student scores. This comes as no surprise since these students were selected to have similar racial, socioeconomic and academic background.

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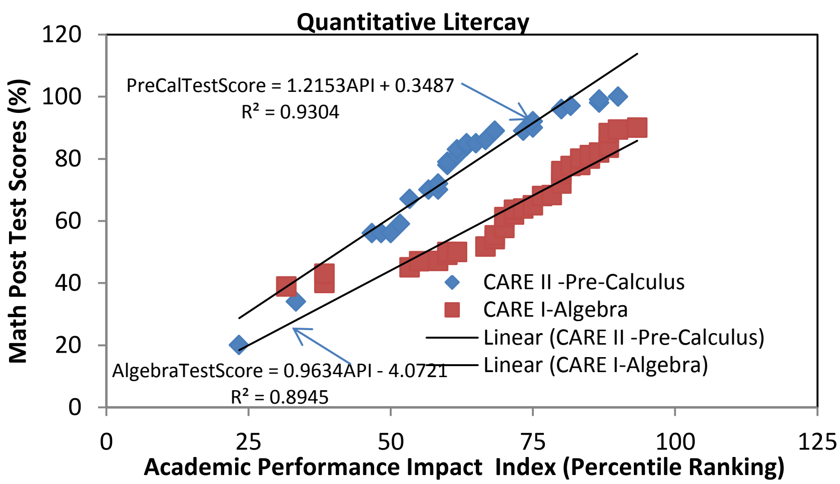

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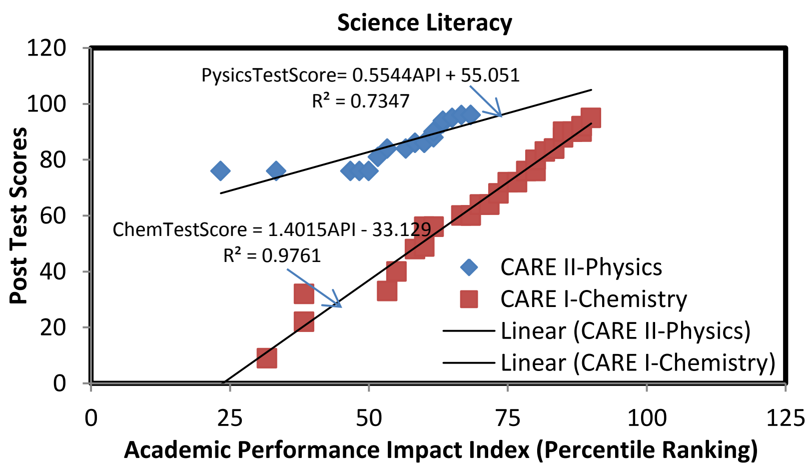


(b)

Figure 9. Impact of normalized API on post-test scores for (a) quantitative (Math), and (b) science (chemistry and Physics)

The enrichment of API skills impacted the physics course more than chemistry course. This observation, though expected, is very significant. Since previous ANOVA data show no statistically significant difference between the CARE groups, it is believed that the observed difference in the impacts on physics and chemistry is due mainly to the nature of the courses, more abstract nature of physics than chemistry, therefore benefiting more from enrichment of API skills.

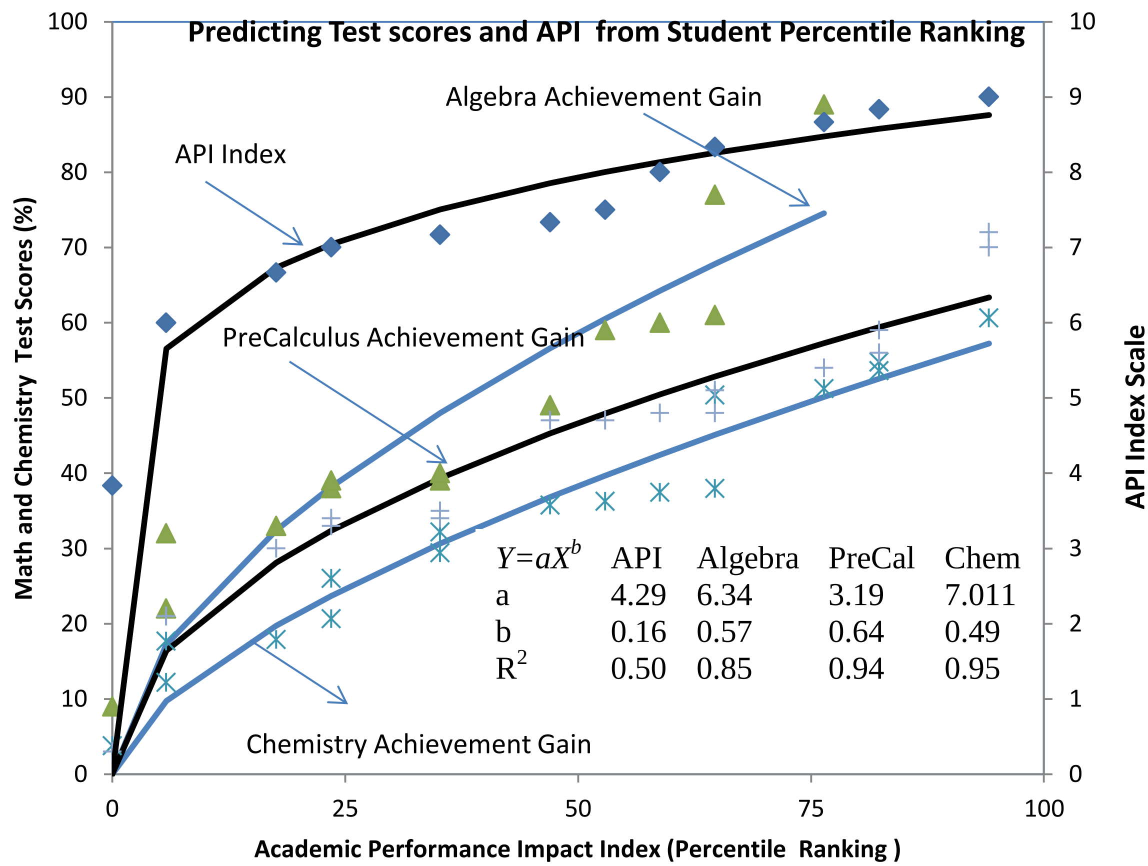
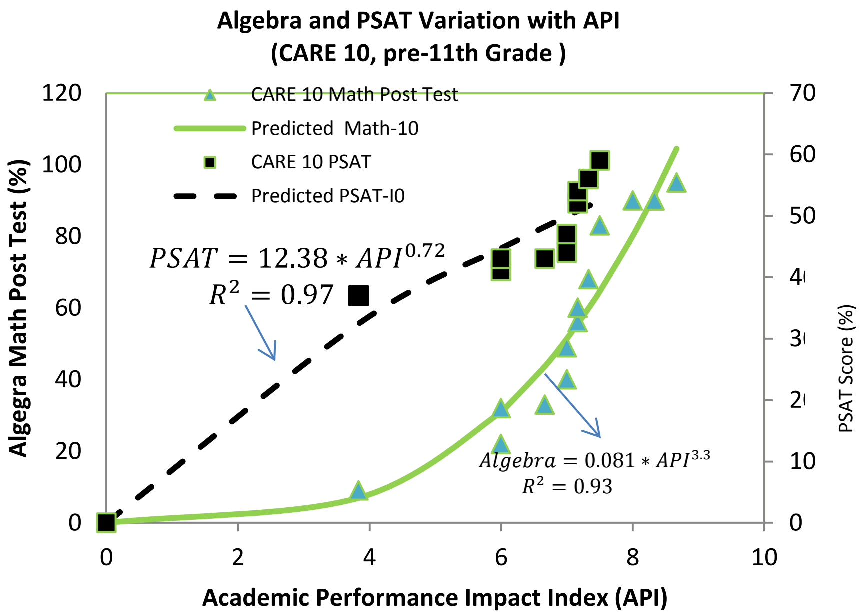


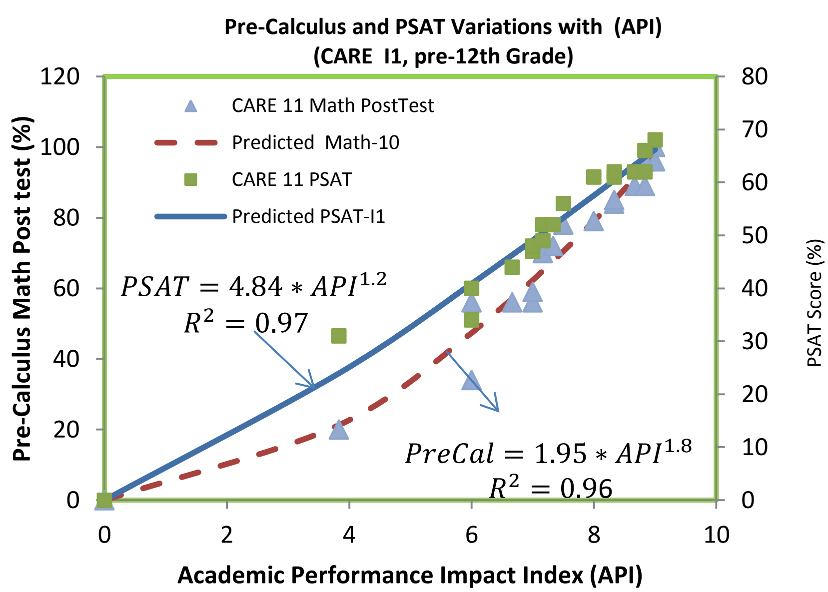
Figure 10. Prediction of math and science test scores from percentile API ranking and API index variation with students performance ranking.

Figure 10 shows the prediction of math and science achievement gain (post-pre test scores) from student percentile API index ranking. The relationships between math and science achievement gains and API percentile index is non-linear and correlated reasonably with a power law with R^2=0.85, 0.94, and 0.95 for algebra, pre-calculus, and chemistry, respectively. The solid curves are the power law prediction fit the experimental data points. As expected, the achievement gain increases with API index values, with a greater gap between math and sciences at higher API values. The API index percentile ranking of 75% (top 25% of class) predicts 40, 50, and 70% achievement gains for chemistry, pre-calculus and algebra, respectively, above the pre-test scores.

Figure 11 shows the prediction of performances in math and Pennsylvania standard achievement test (PSAT) for selected PA students that provided PSAT data. The results show that post- test performance in math is a non-linear power law function of API index, increasing slowly from 0-4 and sharply at API above 5.0 for both algebra and pre-calculus post scores. The degree of non-linearity is about a factor of 2 in algebra, with exponent of 3.3 compared to 1.8 in pre-calculus. However, the dependence of PSAT on API is only slightly non-linear as shown the Figure11 (a & b).



(a)



(b)

Figure 11. Predictions of math and PSAT standardized test scores from API: (a) Algebra PSAT after high school 10^{th} Grade and (b) Pre-Calculus and PAT after 11^{th} Grade

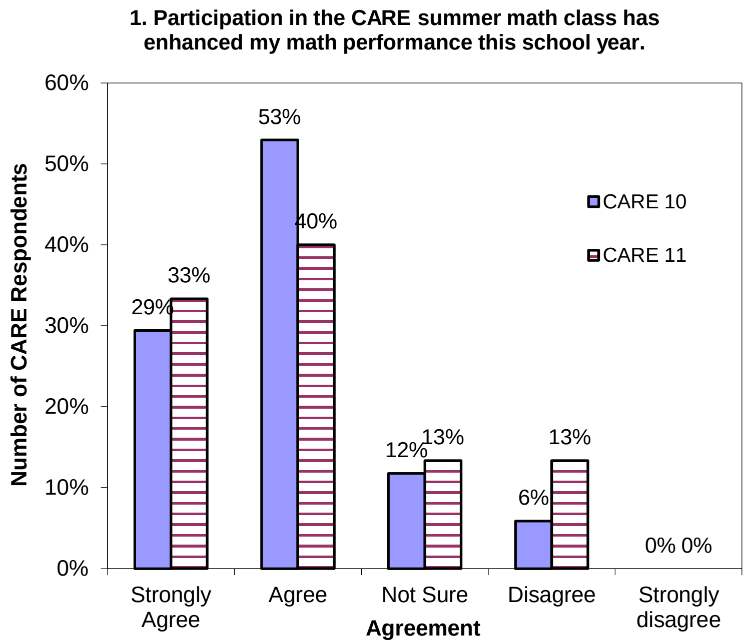


Figure 12. Follow up survey on impact of the academic year performance

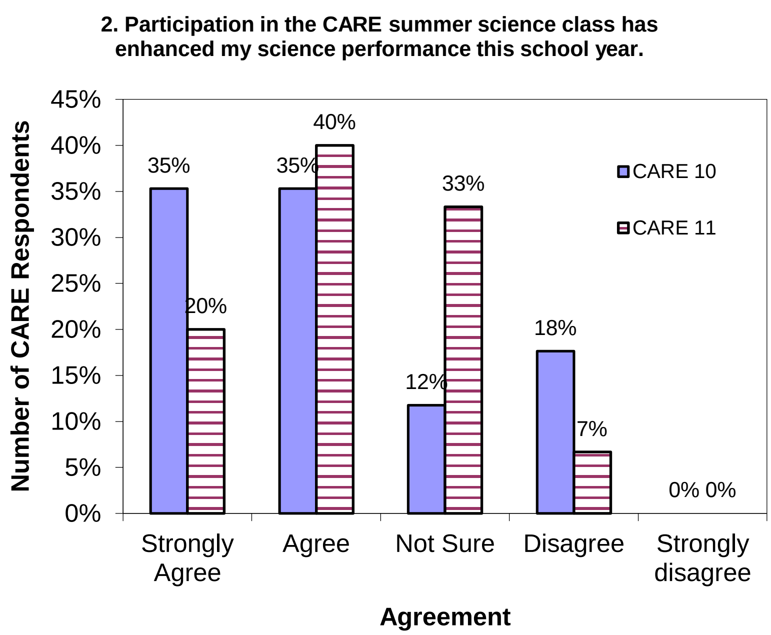


Figure 13. A follow up survey of program science project impact on after leaving the program.

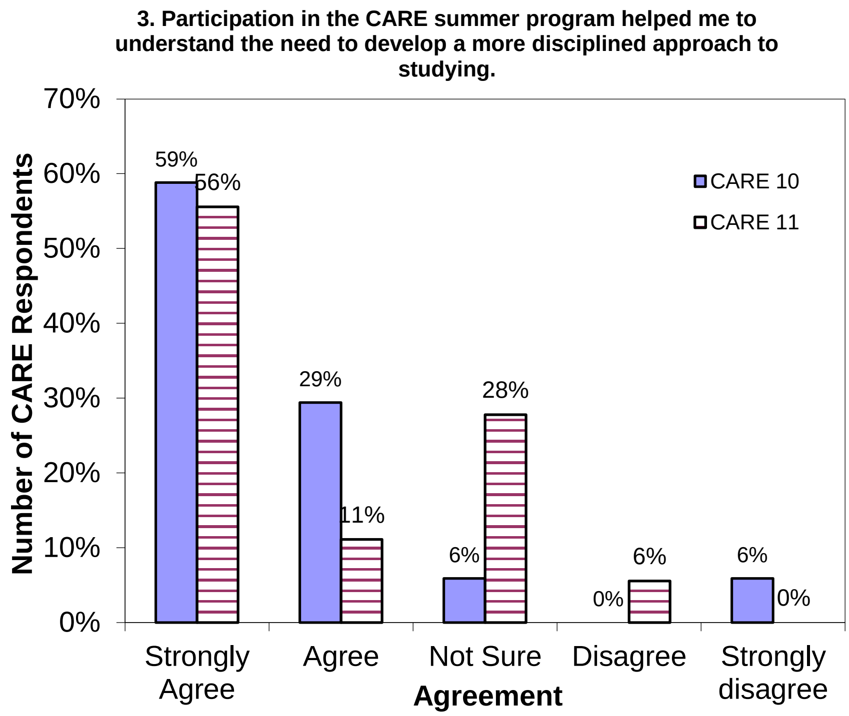


Figure 14. Follow up survey on impact of the academic year performance: discipline to studying

A follow up survey of students that participated in the program indicated that the program impacted the academic performance of over 80% of the students. Figures 12-14 show the tracking of CARE students designed to assess the impact of the program in the participants' continued performance in high school math and science and study skills. More than 80% of CARE students (Figure 12) agree that the participation in the math enrichment class was enhancing their performance in high school, while Figure 13 shows that participation in the science enrichment class was impacting 65% of the participants in high school science class. Overall, the CARE program helped 78% of the participants develop a disciplined approach to studying (Figure 13).

Summary and Considerations

Through the use of survey findings for the overall CARE project, as well as for each component, this paper has demonstrated that participants found significant value in their participation in the summer program. Project was most effective in providing a pathway for educational growth, strengthening study skills and understanding, building success in science and math, enhancing the ability to manage time and organize work, preparing for the next step in science, engineering and mathematics education, and exposing students to knowledgeable and respectful instructors. Self-confidence remains the lowest (54%) for I students who still appear to be intimidated by math and science compared to 11 students (67%). In the ratings of the overall quality of the program, there were no ratings below the 'good' category.

Despite the mixing, most of the non-engineering group found value in the learning experience of the program and in some respects even rated components higher than the participants who saw engineering as their careers from the start. The Program Director responded to this issue in the second year by limiting the enrollment to only those whose stated goal is the engineering field. One potential problem with such a change is that it could deprive some potential participants of a learning experience that this summer's subgroup of non-engineers found valuable. Other alternative strategies are currently being considered.

Given the quality of the responses by the participants, it is clear that the students took the evaluations seriously and gave a great deal of thought to their answers. In particular, their comments about how they overcame obstacles and their suggestions for improving the program provided rich information for program design**.**

Data support the following conclusions:

1. Integration of quantitative/math literacy and science literacy standards in early high school curriculum enriched academic performance impact skills, math and science proficiencies, and educational growth and preparation for STEM career.

2. Use of collaborative and inquiry-based learning significantly impacted academic impact skills for pre-11th and pre-12th grade cohort students.

3. The academic performance impact skills have significant impact on student test scores and educational growths.

4. Enrichment of API skills increased preparation, educational growth and achievement gains in math and science.

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