AC 2007-2002: PROJECT CARE: THE EFFECT OF ENRICHMENT OF ACADEMIC IMPACT SKILLS ON ACADEMIC PERFORMANCE IMPROVEMENT (API) FOR STEM CAREERS

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Project CARE: The Effect of Enrichment of Academic Performance Improvement (API) Skills on Performance in Math and Science

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Abstract

Critical and Analytical Reasoning Enrichment (CARE) program under the Pitt Engineering Access Program (PECAP) identified analytical skill deficiency and 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 under-represented groups into science, technology, engineering and mathematics (STEM) fields. The Project CARE strategy of the solution of the identified problem is based on four fundamental premises: (1) enrichment of the *Academic Performance Improvement (API)* skills - critical thinking, analytical reasoning, quantitative literacy, and problem solving skills will minimize the barriers that hinder students' performance and attraction to STEM careers, (2) use of collaborative learning (such as learning-by-design using engineering projects, hands-on-science and engineering, and technology) 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 also continue through college until STEM degree completion. The project defines A*cademic Performance Improvement (API)* skills index as the difference between the pre and post tests results. The three-year pilot program overwhelmingly indicates that CARE 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. CARE contributed to 86% 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. Project CARE resulted in a systemic change in the way students are given access to an engineering career. The lessons learned in the course of the three program years are also discussed in details.

1. INTRODUCTION

The face of American society continues to change as we experience national demographic shifts in our ethnic populations. The Department of Labor statistics reflect that African-Americans, Hispanics, Asians, American-Indians, and other minorities account for 59 percent of new workers between 1998 and 2008 [1]. In addition, 60 percent of women 16 years of age and over already make up 47 percent of America's 140 million labor force. In response to the demographic changes in population, over 75 percent of America's biggest and best corporations nationwide have implemented diversity programs to increase the minority talent pool to more adequately reflect today's population realities. Minority enrollment in engineering peaked in 1992-93 at 15,181and declined by 8.5 % in 1997-98 [2]. Fifty percent of all minorities engineering enrollment are in just 39 institutions (11 % of engineering schools in the nation), and only 34% of the institutions contribute to the pool of BSE degree minority recipients. Of the 25 engineering schools that are top ranked by US News and world report, only 5% exceed the national average of minority freshman enrollment, and only 7% exceed the national minority graduation [2]. Many universities, federal and state agencies across the nation are responding to the global need for diversity because it is an effective way to serve an increasing heterogeneous society and is, therefore, essential in preparing a 21st century engineer for effective communication and innovations of cross cultural divides.

The need to channel under-represented 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 under-represented minority students. National figures show that fewer and fewer African-Americans are receiving Ph.D.'s in the sciences. 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 [3-8]. The most common of these barriers were identified by others [9-12] as: (1) deficiencies

in K-12 activities that relate STEM to real world experience, (2) insufficient hands-on activity in K-12, and the (3) lack of solid preparation for college work and the conceptual basis for further development, and (4) over-reliance on SAT scores. The American Association for the Advancement of Science Project 2061 [9] had 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. 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. The International Technology Education Association [10] and the National Research Council [11] recommend that this be done by (1) following a technology content standard with well defined guiding principles, (2) including a common set of expectations of what the students should learn, (3) providing a basis for cognitive development, (4) promoting content connections with other field, and (5) encouraging active and experiential learning.

2. PROPOSED SOLUTIONS

The CARE project was designed to systematically enrich *Academic Performance Improvement (API)* skills through a series of college level math and science activities for talented 10th (CARE I) and 11th (CARE II) grade students. The *Academic Performance Improvement (API)* skills are defined as those skills that when enriched or advanced impact the academic performance of students in STEM careers. These include such skills as - critical thinking, analytical reasoning, quantitative literacy, study/time management skills, and problem solving skills. Our basic premise is that the lack of 75% of these skills will hinder students' performance and attraction to STEM careers. Thus, strategic enrichment of these skills will better prepare students for science and engineering and should begin earlier in the middle and high school grades. In addition, support services for these students must also continue through college until they graduate. Project CARE primary aim was to design and implement program activities to enrich these skills, measure the effectiveness of the project in accomplishing the goals and the effect of improvement of API on students' performance in math and science.

The project solution was designed to address the areas that serve as barriers to under-represented students' entry into STEM majors and subsequent careers, namely: less than challenging mathematics and science instruction exacerbated by poor study skills and limited or no hands-on experience to explore and maximize their individual learning styles. The summer session's rigorous math and science courses advanced the knowledge that students were gaining through their high school classes—classes that often focused on formulaic solutions rather than comprehension of mathematical and scientific concepts. Previous low scores appeared to be a consistent indicator of potential problems, therefore demonstrating the value of focusing the program's efforts on cultivating essential math skills. Hands-on engineering projects, nonexistent in most high school curriculums, provided a link between the conceptual learning of the classroom and the real world applications in an engineering environment. SAT preparation classes were provided through a nationally recognized test preparation organization which ensured that students had the most competitive scores that they had the potential to achieve. In addition, CARE students had opportunities to interact and work with engineering faculty and students allowing them to begin to build relationships and become comfortable in the University environment.

3. PROGRAM DESCRIPTION AND IMPLEMENTATION

The CARE Program is a summer and academic year pre-engineering program for talented 10th and 11th grade students. Project CARE as titled in this paper is the summer residential component program of the CARE Program that targets members of groups traditionally under-represented in engineering fields and who reside in Pennsylvania, Maryland, Ohio, District of Columbia, Virginia, New York and New Jersey, with 50% of the participants from the Pittsburgh community. More than 85% of engineering students at the School of Engineering come from these states. CARE expands the students' cognitive, critical and analytical reasoning skills to prepare them for an undergraduate career in engineering. The primary mission of the CARE Program is to create a systemic change in the pipeline for increased access to an engineering career for under-represented students by helping them with early skills development that will positively impact the quality of their academic performance (math and science content, GPA, class ranking, SAT) by the end of the high school senior year. The expected outcome is for students to be academically prepared to qualify for direct admission to a competitive engineering school such as the University of Pittsburgh. CARE targets those students who are highly motivated and have a strong commitment to pursue an engineering career, and are within the top 25% of their class, or may be academically disadvantaged with "excellent" grades in weak K-12 science and math curriculum. CARE serves as a catalyst for higher academic performance to ensure that students are academically prepared to enter a quality engineering program when they

graduate from high school.

Project CARE targets two groups-Pre-11th (CARE I) and pre-12th (CARE II). The goal of CARE I is to enrich academic preparation in college algebra, engineering learning tools, and technical writing/reading of high school pre-11th grade students from the selected regions. The outcomes of CARE I are to: (1) increase the average score of pre-11th grade participants in mathematics competence in algebra, trigonometry, functions and graphs, and in general quantitative literacy skills, (2) increase the basic writing/reading and technical communication skills of the pre- 11th grade participants, and (3) increase students' early awareness of engineering careers and provide informal experiences that promote an expectation for excellence and interest in an engineering degree.

To make a solid improvement in the performance of pre-11th grade participants in algebra, trigonometry, functions and graphs, and general quantitative literacy skills (*CARE I Objective 2*), courses in *Foundational Mathematics I,* covering college algebra and problem solving to help students solidify their basic (Algebra I and II) mathematic skills and give the students an opportunity to develop the problem solving skills necessary to succeed in an engineering major were designed and implemented. Solid improvement in basic writing/reading, problem solving and technical communication skills of the pre- 11th grade participant (*CARE I Objective 2*) relies on three courses: Basic Writing/Reading I –designed to enhance the students' technical writing and engineering communication skills and give them an opportunity to explore different writing techniques; *Engineering Tools I* –10 – 15 hour engineering projects facilitated by faculty and graduate students using hands-on-engineering scientific methods in a cooperative learning environment to interactively expose students to various math and science areas and their relation to engineering; and *Study Skills I/ SAT Prep* –to help students develop the study skills necessary to excel in a college environment.

The goal of CARE II is to integrate API skills acquired in CARE I into college level calculus and chemistry courses as a foundation for an engineering education. The target group is pre-12th grade engineering bound students, including those graduating from CARE I. The expected outcomes of CARE II are (1) better preparation for the college level calculus and chemistry courses for engineering students, (2) to improve competence in problem solving and technical communication by the end of the 12th grade, and (3) to increase motivation of high school youths for STEM careers.

To prepare a measurable number of the participants for the college level calculus and chemistry courses that are typical for engineering students (CARE II Objective 1.), the following courses were designed and implemented: ***Foundational Mathematics II*** designed as an introduction to pre-calculus covering functions and graphs, trigonometry, identities/equations and analytical geometry and their integration to calculus and engineering. The course emphasizes problem solving/logic using functions and graphs, word problems, puzzles and other use of non-traditional tools to increase critical thinking skills, and reasoning/logic and problem solving skills necessary to succeed with a major in engineering*;* ***Introduction to Engineering Science I Chemistry*** designed as an introduction to chemistry with an emphasis on problem solving and critical thinking skills. The course introduces measurements and classification of matter; atoms, molecules and ions; equations and moles concepts; chemical reactions, and basic stoichiometry.

To acquire competence in problem solving and technical communication by the end of the 12th grade, the following three courses/instructional sessions were designed and implemented (CARE II Objective 2.): ***Technical Writing/Research/Reading II*** is designed *to* enhance students' technical writing and engineering communication skills and give them an opportunity to explore scientific writing techniques; ***Engineering Tools II*** focuses on hands-on-engineering with computers, graphic calculators, basic electrical circuits, and engineering faculty/students to expose students to various math and science areas and their relationship to engineering; ***Study Skills II/SAT Prep*** helps students develop the study skills necessary to excel in a college environment.

To increase students' early awareness of engineering careers and provide informal experiences that promote the students' interest in an engineering degree (CARE I and CARE II Objective 3.), CARE implemented the following support initiatives: ***Academic and Tutoring Support*** provides academic advising, tutoring, and academic assessment and remediation in science and mathematics, and counseling about their choice of a compatible engineering major throughout their years in the program; ***Career Exploration Workshops I*** helps students take career interest inventories, learn about engineering and science careers through guest speakers and discuss financial aid options. Parental activities (such as picnics and workshops) were sponsored to enhance a parent's ability to

monitor their child's academic performance and assist with college planning; ***Cultural Awareness*** *is* designed to help students embrace and value diversity; and ***Individualized peer-mentoring*** between high-achieving University of Pittsburgh students and the 11^{th}-12^{th} grade high school students. Selected University of Pittsburgh upper class minority science and engineering students will be assigned to the participating 11^{th}-12^{th} grade students to provide a role model for the high school students, encouraging them to set academic and personal goals for high achievement.

4. EVALUATION/ RESULTS AND ACCOMPLISMENTS

4.1. Evaluation/Assessments

Critical thinking, analytical reasoning, quantitative skills, and problem solving skills were identified as the key *academic improvement skills* that if enriched can increase achievement in STEM careers. Assessment instruments were designed to measure the (1) the effectiveness of the CARE program in enriching the *academic performance improvement (API) skills* and (2) the effect of improvement of API on the students' achievements in math and science.

CARE solicited feedback from participants in a variety of ways. During the summer session, students completed a "Weekly Reflection" as part of the formative assessment that provided information about their learning experience in each class during the week. These forms were read at the end of each week and concerns and questions were shared with instructors as needed. Students also completed a comprehensive survey at the end of the summer that addressed all aspects of the summer program. During the school year, students completed evaluations at the end of each program activity and completed a survey at the end of the year. Instructors were asked to complete weekly progress reports during the summer to evaluate students' performance as outstanding, satisfactory or unsatisfactory. Instructors also administered pre-and post-tests in all classes and provided a final evaluation that was shared with the student and parents. CARE retained the services of an external consultant who assisted in the development of the survey and its modification.

4.2 CARE Project Results

4.2.1. Progress in Accomplishing Specific CARE I Objectives

(1) Increase the achievement of pre-11^{th} grade participants in algebra, trigonometry, functions and graphs, and in general quantitative literacy skills.

All students who attended the 2003 CARE I summer program completed three courses designed to increase their achievement in math and quantitative literacy skills-- College *Algebra, Problem Solving and SAT Math Preparation*. Pre- and post-tests were administered to measure student growth in algebra over the course of the summer. On the pre-test, the most frequent score was 0% and the highest was 12%, indicating that the students did not have initial knowledge of the materials On the post-test, the highest score was 96%; the median was 78% and the mean was 87%. The scores indicate that in this class, students made significant progress over the course of the summer session.

Fig. 1 shows a comparison of pre-and post-tests to assess the performance of the participants in College Algebra. The pre-test was based on content of the learning objectives while the post-tests tested the same concepts but at a mastery level, including the use of technology. CARE defines improvement or performance index in this context as the difference between the pre- and post tests results. The college Algebra results in 2003 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% improvement) and from a 0% to a 79% score (79% improvement). Neglecting the scatter in the data due to the variability in the students' high school level of preparation, the algebra pre- and post-test results show that 11 out of 15 students in 2005 made significant improvements in mastering the subject matter with 35% improvement among those students who scored lowest on the pre-test compared to 25% improvement among those that scored highest in the pre-test. This shows that the impact was more (+10%) on the academically changed students who scored lowest in the pre-test. All CARE I students performed at significantly different levels (between 45- 80%) on the post-test.

The survey and pre-and post-tests results overwhelmingly indicate that CARE succeeded in preparing students for college level math and chemistry instruction as well as enhancing their ability to excel in their senior year of high school. Most of the participants (93%) agreed that chemistry and the associated lab contributed to their educational growth and will be useful for their college career; 79% agreed that engineering tools contributed to their educational growth. 86% agreed that the knowledge acquired contributed to their educational growth. Study and communication skills received the highest marks as critical in sustaining education growth.

(2) Increase students' early awareness of engineering careers and provide informal experiences that promote an expectation for excellence and interest in an engineering degree.

The major engineering awareness activity during last year's summer session was the Race Car Project facilitated by the Mechanical Engineering Department. Over the course of the summer session students learned Solid Works and designed model race cars on the computer. The cars were built in the prototyping lab, painted by the students and raced as a culminating activity for the project. This hands-on activity exposed students to typical activities of a mechanical engineering professional, enabled them to master a new computer program and challenged them to analyze car features that would contribute to the design of a racecar. During the school year, CARE I students attended hands-on engineering activities on Saturday mornings. Like the summer race car project, these sessions increased students' awareness of what various engineering disciplines involved. Students participated in sessions in electrical and mechanical engineering and materials science. The program investigated the effect of the CARE summer math, science, study skills, and engineering projects on the students' educational growth and preparation for the next high school academic year. Fig. 2 shows that CARE students agreed that *Logic/Problem-Solving Skills* contribute to their educational growth and will be useful for their college career (67%) while 53% 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 (89%) and would be useful in their college career (94%). Students also saw communication skills to be important in educational growth (75%) and college career (93%).

4.2.2. Progress in Accomplishing CARE II Objectives

(1) Prepare participants for the college level math and science typical for engineering students.

CARE II assessed the impact of Chemistry, engineering tools and pre-calculus on quantitative and technological literacy and the impact of study and communication skills in improving learning. A college physics course was used in 2005 to assess scientific and technological literacy for CARE 1 students. The median pre-test score for chemistry was 43% and the mean score was 47%. Post-test median was 71% and mean 72%. For Pre-Calculus, the median score was 47% for the pre-test and the mean was 43%. Post-test median was 69% and mean 84%. These scores indicate that in all classes students made significant progress over the course of the summer session.

Fig. 3 compares the quantitative literacy of CARE II students using pre- and post- tests in pre-calculus for the program years. It is clearly observed that students who scored lowest in the pre-test improved higher (50% and 80% improvement in years 2004 and 2005, respectively) compared to (30% and 45% in years 2004 and 2005 respectively) for students who scored highest in the pre-test, a 20% difference in program impact on these two groups of students. The was wider in 2003 (Fig. 3a) that shows 50% for students who scored lowest in the pre-test compared to 25% improvement for students that scored highest. CARE II students performed at relatively the same level (above 80%) on the post-test in 2005 as the program appeared to have made greater impact in 2005 than in 2004. Survey results reveal that 93% of CARE II students believe that the summer session instruction reinforced their problem-solving skills in math and science.

Similarly, Fig. 4 compares the scientific and technology literacy of CARE II students using chemistry pre- and post-tests scores, respectively. The results clearly show that CARE II students who scored lowest in the chemistry pre-test improved higher (35%, 45% and 40% improvement in years 2003, 2004 and 2005, respectively) compared to (20%, 22%, 20% in years 2003, 2004 and 2005, respectively) students who scored highest in the chemistry pre-test, an average of 20% difference in program impact on these two group of student. This may be attributed to "over-confidence factor" of this student group at the beginning. The project found that this group is most likely to agree that the program was not challenging enough and hence take a more relaxed attitude toward studying than those that tested lower. In science, 16 out of 16 students made improvements from the pre-test to the post-test. Physics was

added in 2005. It is very interesting to observe from Fig. 4d that all CARE II students had the same background in physics at the pre-test but performed at relatively the same level (above 80%) on the post-test. This shows that inquiry based instructions in physics impacted the students on exactly the same level. The fact that this is the same group of students who scored very low in the Pre-Calculus pre-test makes this a remarkable impact of inquiry based approach to teaching physics. It also shows that an inquiry based approach to teaching science is more effective in students' understanding of physics than chemistry.

(2) Build competence in problem solving and technical communication by the end of 12th grade.

CARE II students participated in SAT verbal and math preparation classes during the summer session. The primary goal of these classes was to enhance students' performance on the SAT; a secondary goal is to sharpen their problem-solving ability. The engineering project class—the race car, also provided opportunities for students to enhance their problem-solving abilities. In lieu of technical communication, the writing class focused on essay writing. This change was implemented because we believed that the high school seniors' ability to write essays would have immediate impact on their college applications and acceptances as well as on scholarship opportunities. End-of-program survey results indicate that over 80% of the participants believe that enriching their critical thinking skills enhanced their problem-solving skills (Fig. 5).

(3) Motivate high school youth to follow their individual career interests in the fields of engineering and technology.

CARE presupposes that strategies such as *collaborative learning, learning-by-design using engineering projects*, *hands-on-science and engineering*, and *use of technology* contribute to motivation and interest in STEM careers. Figs. 6-8 show the impacts of these four major strategies. The three year average shows 60% agreement that collaborative learning strategy improved students' understanding of math (Fig. 6), engineering projects helped 78% of the students gain better understanding of engineering concepts (Fig. 7). It is to noted that the engineering project activities in 2005 was more intense and better focus on engineering than previous years' projects which explains the apparent difference in the data. Over 75% agree that inquiry-based hand-on-experienced helped their understanding of lecture materials (Fig. 8), and 73% agree that the use of technology (graphic calculator improve their interest and learning (Fig. 9). In addition, 83% of the students reported continuous assessment through classroom assignments and testing exposed them to challenging applications or extensions of the course content (Fig. 10). On an effectiveness scale of 0-10 (10 as most effective), CARE student rated the CARE program as 6.5/10 (or 65%) effective in increasing their motivations and interests in STEM careers.

CARE proposed program activities contributed significantly to the educational growth of the participants. Figures 11-14 reflect how students viewed participation in the CARE program. Over 75% indicated that participation in the program has contributed to their confidence in math and science problem solving abilities (Fig. 11), contributed to overall educational growth of more than 88% of the students (Fig. 12), improvement in self confidence and math and science problem solving skills (Figs 13 and 14). Combined, the survey results suggest that the summer session math-based courses did impact students' math and quantitative literacy skills

Figure 15 demonstrate the effect of improvement on the program's five *academic improvement skills* -analytical skills, critical thinking skills, problem solving skills, and quantitative skills on the students' academic performance. These aspects were measured in the Program Summary Instrument by asking the students to rate—on a scale of 0 to 10. The results show the average rating given to these aspects by all participants by year and within each program. Scores for the Summer Engineering Academy (students in SEA program) are included here for comparison. The SEA students are student already admitted into the school for engineering careers. Blanks in year 2005 indicate the program was not offered that year. Most of the mean ratings fall in a respectable range, between 6 and 8 on the scale, representing 60% and 80% effectiveness, respectively. The number of high average scores (those above 7) occurred in the areas of analytical skills, critical thinking skills, and problem-solving skills indicating that CARE improved those skills to 70% of the participants. In general, average ratings were lower in 2005, particularly for the CARE II group. There is some question as to whether changes made to the curriculum in 2005 were viewed negatively by some participants who may have expected more challenging offerings. It should be noted that in 2005, the pace and level in math instructions were modified (from Advanced to Basic) to accommodate the variability in the students initial preparation and motivation for STEM careers and to see if the program can convert

students (25% of the Cohort) who had initial little or no motivation for STEM to consider STEM fields. The results show a significant drop in program effectiveness (65.5% with 2005 data compared to 69.3% without 2005 data). From the free open-ended response statements, while the non-prospective STEM students indicated that the program may have been at the correct pace for them, the STEM students who expected the more challenging offerings in the first two years to continue saw the program to be less challenging and effective for their interests. The data suggest that changes made to the curriculum in 2005 may have affected the perception of the continuing CARE II students (60% effectiveness in 2005 compared to 78% in 2004) and therefore the overall rating (18% drop for CARE II students alone) of the program. Overall, the program has had a positive impact on students' academic improvement in science and math by enhancing students' analytical, problem-solving and critical thinking skills; the quality of instructors has been very high, characterized by respect for and respect by the participants; high school counselors and teachers are an important resource for recruiting program participants; participants generally feel that the program is a good preparation for their academic and professional futures.

4.3. Discussions of Students' Feedback

Based solely on an analysis of student feedback, the following can be stated:

Course Ratings: The measurement of course ratings are shown in Tables 1 and 2 using an "agreement percentage". In the table, agreement percentages are aggregated over the three-year period for all program participants and are summarized for each of 12 course rating aspects. The average rating for all aspects combined was 82%. The highest combined agreement percentage (90%) was evident for the statement "the instructor respected students; the lowest (71%) was for the statement 'the instructor was challenging and stimulating". Overall, participants rated aspects of instructor performance more highly than aspects related to class logistics or career growth. Over the course of the three-year period, students' perceptions of 12 aspects of the program they participated in remained positive. As the results indicate, agreement percentages varied within a range of 70% to 94%. Year-to-year, the most consistently highly-rated aspects was the performance of instructors (items 3-5, and 10 in Table 4).Consistency of agreement was not evident in some other respects. For examples, item numbers 1 and 2 were viewed less positively from 2003 to 2004, but more positively from 2004 to 2005. There was a notable downturn in items 7 and 8 for 2004-2005 both of which relate to the value of program content to educational and career growth. The final set of items, 9-12, remained essentially stationary, in the 70%-81% range. On all of the positively-worded statements, most of the respondents indicated agreement. Secondly, the figures indicate that the program made substantial improvements in nearly all other aspects from the first year (2003) to the second year (2004), as shown by the number of plus (+) percentages in the column headed "Change, 2003-2004."

The most notable changes occurred in statements related to the overall effectiveness of the program (-28%) and the difficulty of the level of instruction (-25%). This was further indications of the adjustment that the CARE program made to the curriculum in 2005, The emphasis on more basic concepts may have influenced the improvement in participants' views about understanding materials and keeping up with the pace of instruction. However, the change may have also led to the drop in students' perceptions about the educational and career value of the program. It is difficult to test this assumption because of the wording of item 2, "the pace of instruction was appropriate." Unlike the item about "level of difficulty" in the CARE survey (Table 5), this item does not provide a sense of whether the pace of instruction is too fast or too slow. Thus, the Program Summary survey does not have a corresponding way to measure the relative ease or difficulty of the student's learning experience. There is a statistically significant negative correlation between students' feelings that the level of instruction was difficult and their rating of the effectiveness of the program—that is, students who found the going easy were more likely to rate the program lower. The correlation, however, is not a very strong one (0.30), indicating that while a substantial number of students felt this way, there were not enough of them to draw conclusions about a trend.

Figures 16-18 show the tracking of CARE students to assess the impact of the program in the participants continued performances in high school math, science and study skills. More than 80% of CARE students agree that the participation in CARE math enrichment class is enhancing performance in high school by 80% (Fig 16), while Fig. 17 shows that participation in the CARE science enrichment class is impacting 65% of the participants in high school science classes. Over all, the CARE program is helping 78% of the participants develop a disciplined approach to studying (Fig.18).

5. SUMMARY, CONCLUSIONS, AND LESSONS LEARNED

5.1. Summary and Conclusions

Although the full impact of project CARE is still being explored, the program's three years implementation has shown more success than was originally expected. Some high lights of the program accomplishments are summarized below:

1. More than 40% of the program participant's enrolled in STEM careers and about 27% in Pitt's school of engineering alone. Overall, the program has had a positive (70%) impact on students, enhancing analytical, problem-solving and critical thinking skills. High school counselors and teachers are an important resource for recruiting program participants.

2. Participants generally feel that the program is a good preparation for their academic and professional futures.

3. The number of high mean effectiveness scores (those above 7) occurred in the areas of analytical skills, critical thinking skills, and problem-solving skills indicating that CARE improved those skills to 70% of the participants. In general, average ratings were lower in 2005, particularly for the CARE II group. More than 80% of CARE students agree that the participation in CARE's math enrichment class is enhancing performance in high school math classes and impacting 65% of the participants in high school science classes. Overall, the CARE program helped 78% of the participants develop a disciplined approached to studying.

4. CARE defines *academic performance improvement index* (API Index) as the difference between the pre- and post tests results. The college Algebra results in 2003 showed that 16 out of 16 students made improvements from the pre-test to the post-test. The trend was also observed throughout the program years. CARE resulted in API of 0.35 (35% improvements) in mastering the math subject matter among those students who scored lowest on the pre-test compared to 25% improvement among those that scored highest in the pre-test. This shows that the impact was more (+10%) on the academically challenged students who scored lowest in the pre-test.

5. The results clearly show that pre-12 students (CARE II) who scored lowest in the chemistry pre-test improved 20% higher than those who scored highest, a factor attributed to the "over-confidence factor" of this student group at the beginning. The project found that this group is most likely to agree that the program was not challenging enough and hence took a more relaxed attitude toward studying than those that tested lower.

6. Inquiry based instructions in physics impacted the students exactly the same but varied in chemistry and appear to be more effective in students' understanding of physics than chemistry.

7. The survey and pre-and post-tests results overwhelmingly indicate that CARE succeeded in preparing students for college level math and chemistry instruction as well as enhancing their ability to excel in their senior year of high school. Although 43% agreed that the pace of instruction in pre-calculus was appropriate and (67%) indicated the pace was too fast, 86% agreed that the knowledge acquired contributed to their educational growth.

8. Overall, participants rated aspects of instructor performance more highly than aspects related to class logistics or career growth. Over the course of the three-year period, students' perceptions of the 12 aspects of the program they participated in remained positive. As the results indicate, agreement percentages varied within a range of 70% to 94%.

9. Students who have low interest and/or motivation for STEM career could not be significantly motivated for STEM careers and rigorous curriculum to challenge students who have initial interest and motivation is more effective in increasing and sustaining the their interest in STEM

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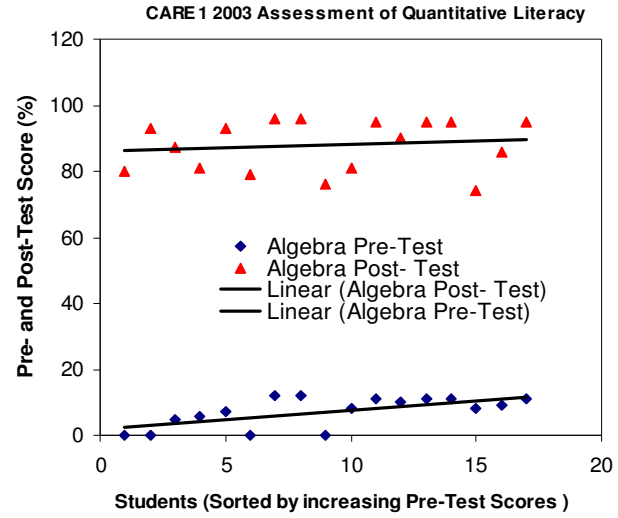
Figures



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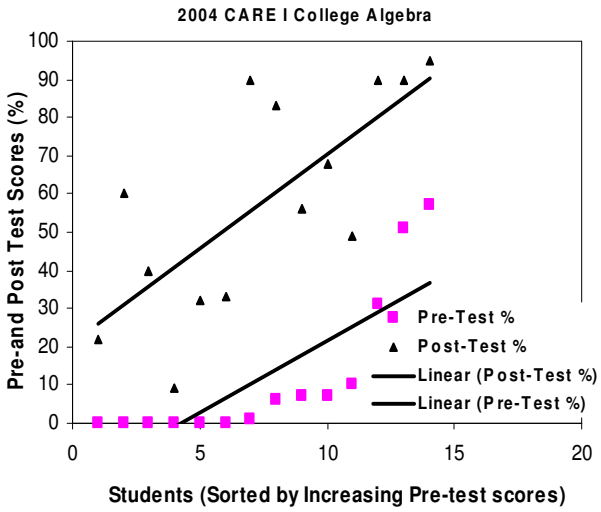

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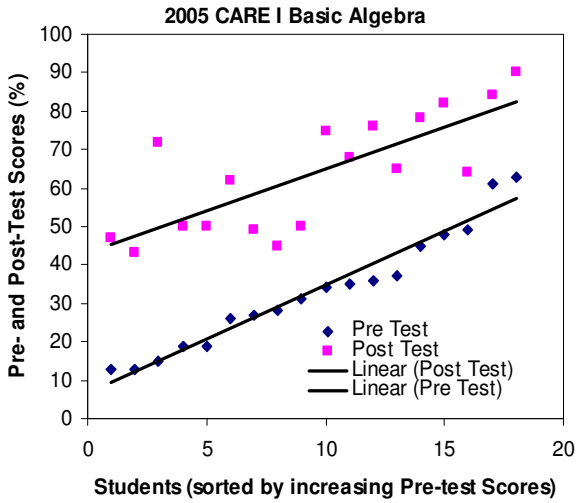


(c)

Fig 1: API Assessment of on quantitative literacy based on performance in college Algebra pre-and post-tests for pre-11th grade CARE II students for (a) 2003 and (b) 2004 and (c) 2005

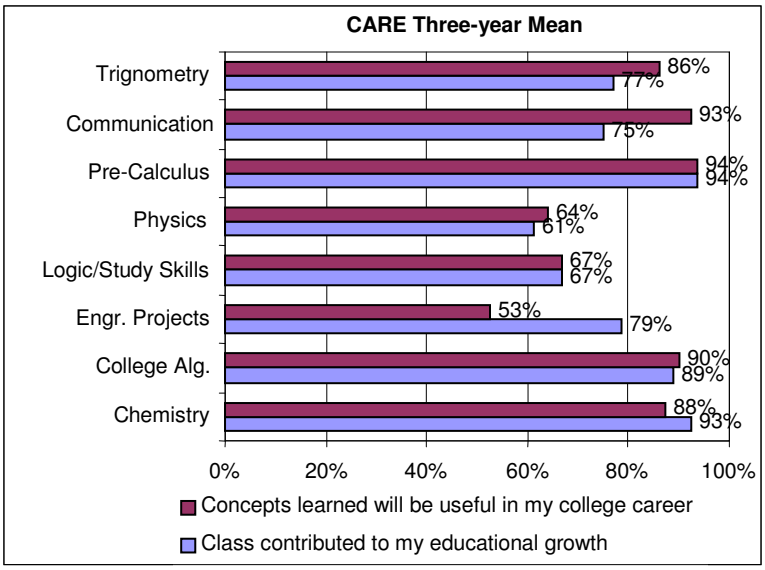
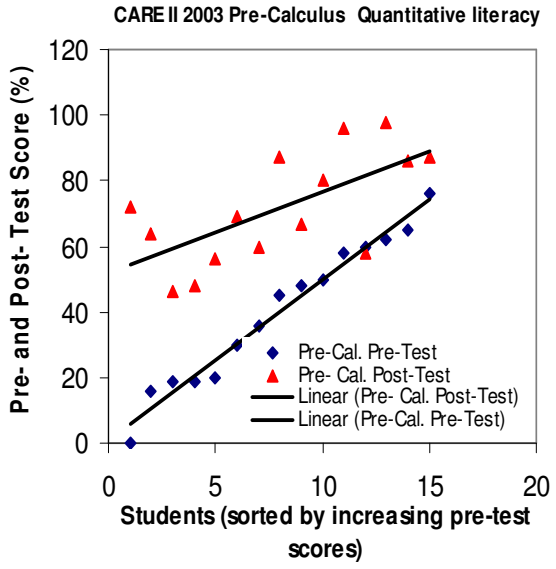


Fig. 2. Impact of CARE summer enrichment courses offering on educational growth and preparation for high school academic year



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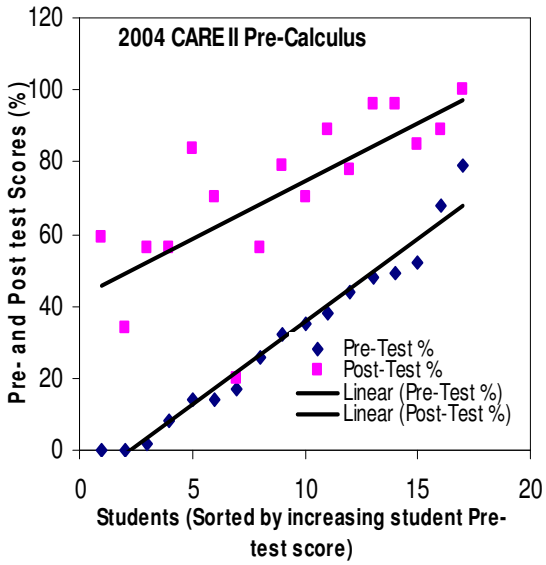

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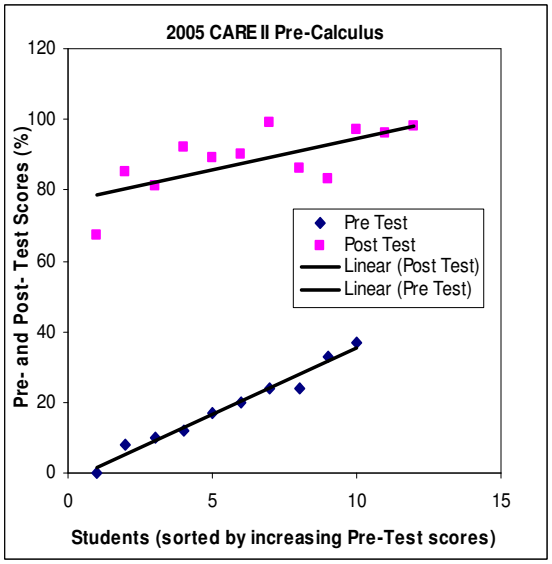

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Fig. 3. API Assessment of on quantitative literacy based on performance in pre-calculus pre-and post-tests for pre-12th grade CARE II students for (a) 2003 and (b) 2004 and (c) 2005

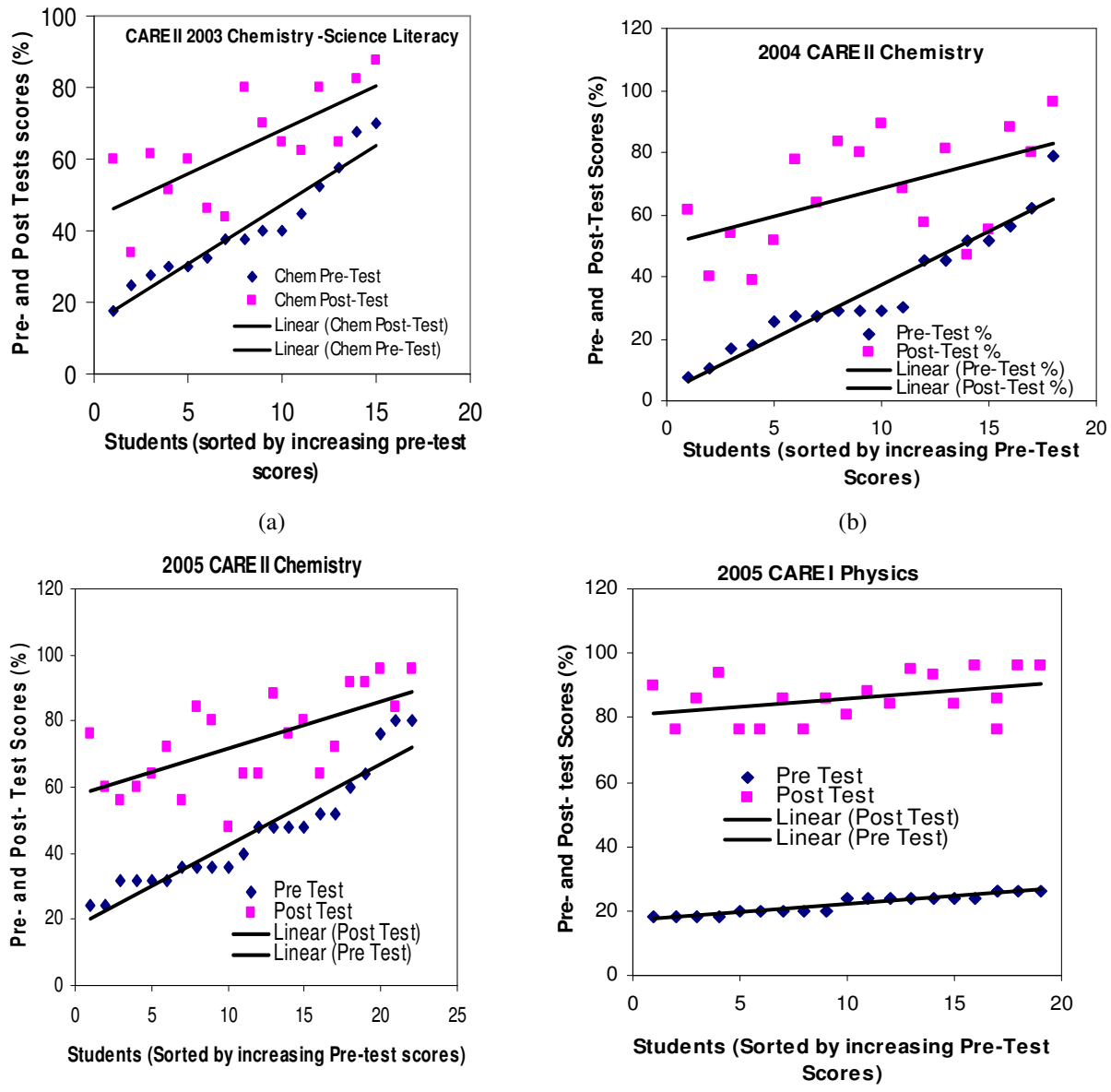

Fig.4. API Assessment of science literacy based on performance in (a) 2003 chemistry (b) 2004 chemistry (c) 2005 chemistry for pre-and post-tests for pre-12th grade CARE II students and (d) physics for pre-and post-tests for pre-11th grade CARE I students.

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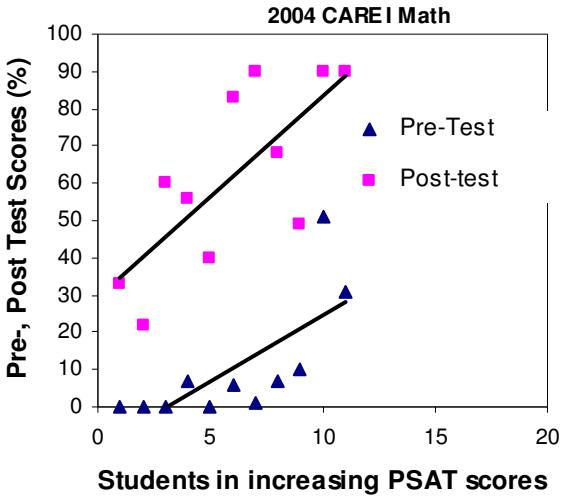

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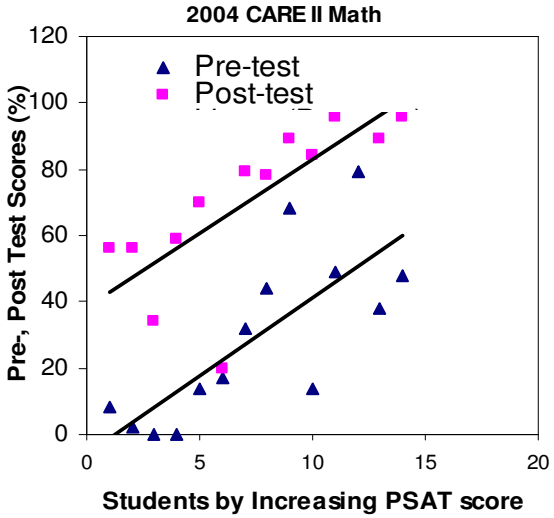

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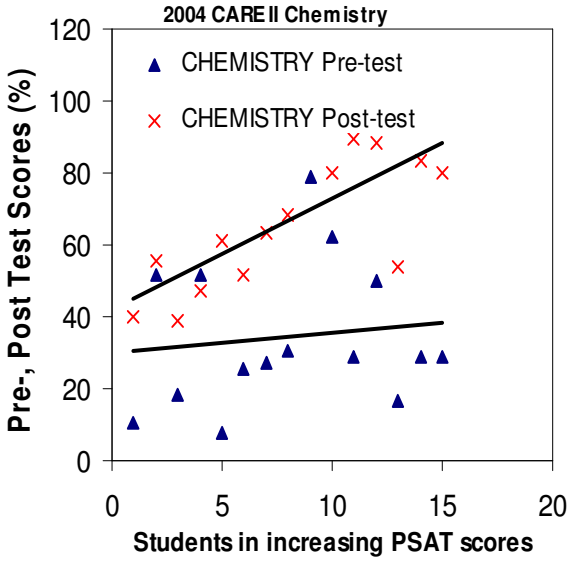
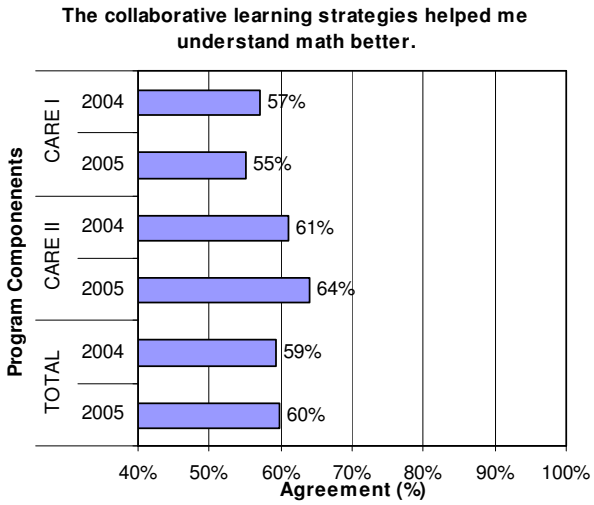


(c)

Fig. 5. API Correlation of CARE students' achievements in (a) CARE I Math(b) CARE II, and (c) chemistry with PSAT scores



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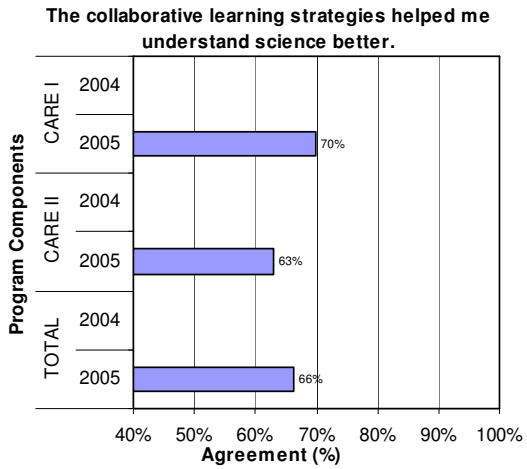

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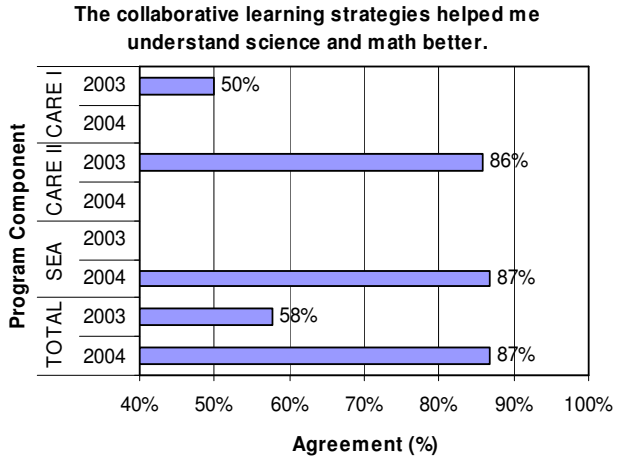

(c)

Fig. 6. Impact of collaborative learning strategy on understanding (a) math, (b) science and (c) math and science learning

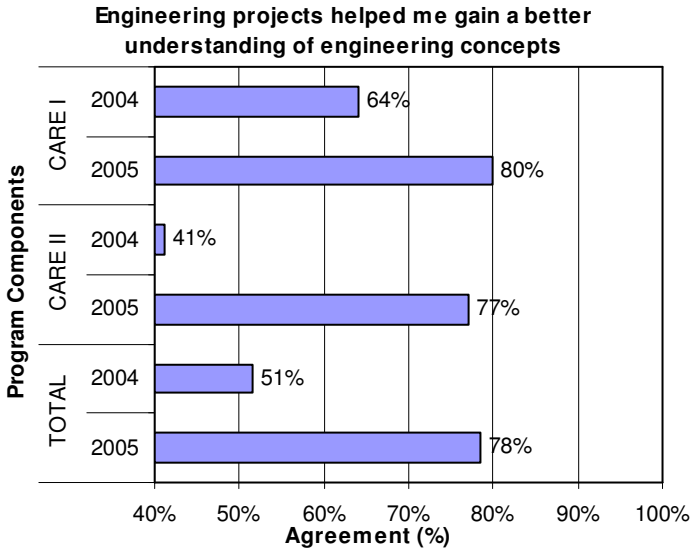

Fig. 7. Impact of engineering project impact on understanding engineering concepts

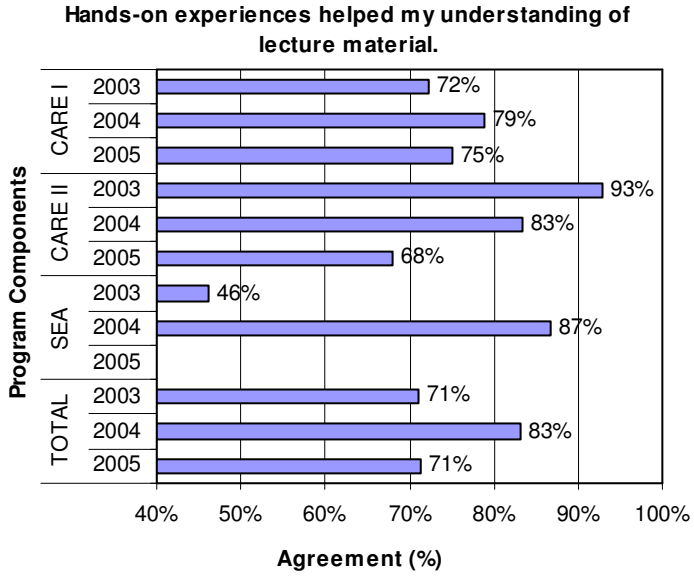

Fig. 8. Impact of hands-on- experience on understanding lecture materials

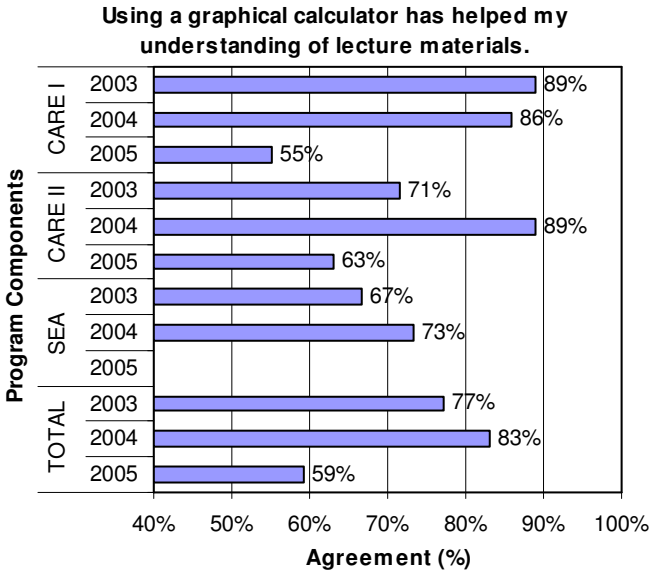

Fig. 9. Impact of use of technology on students learning

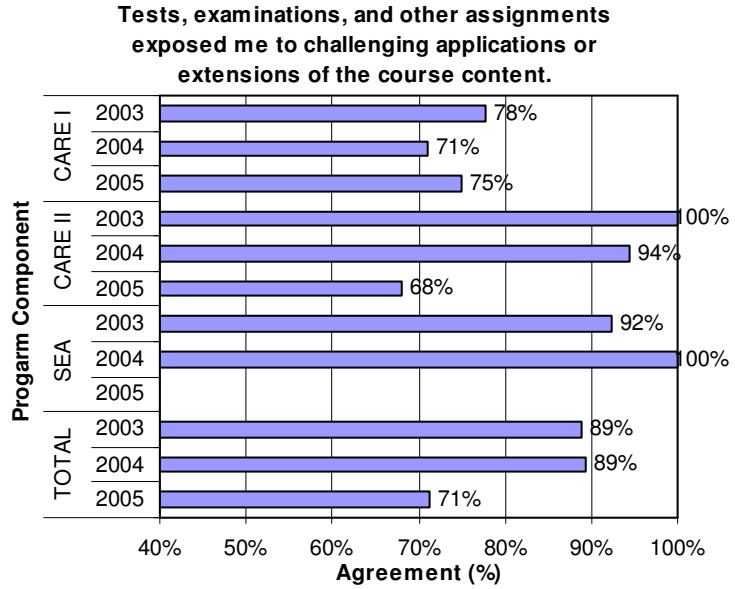

Fig. 10. Impact of continuous assessment on educational growth

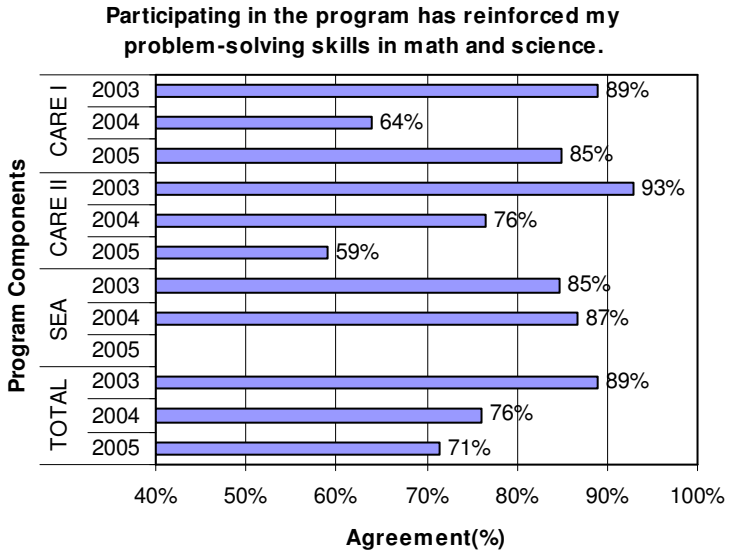

Fig. 11. CARE impact on problem solving skills

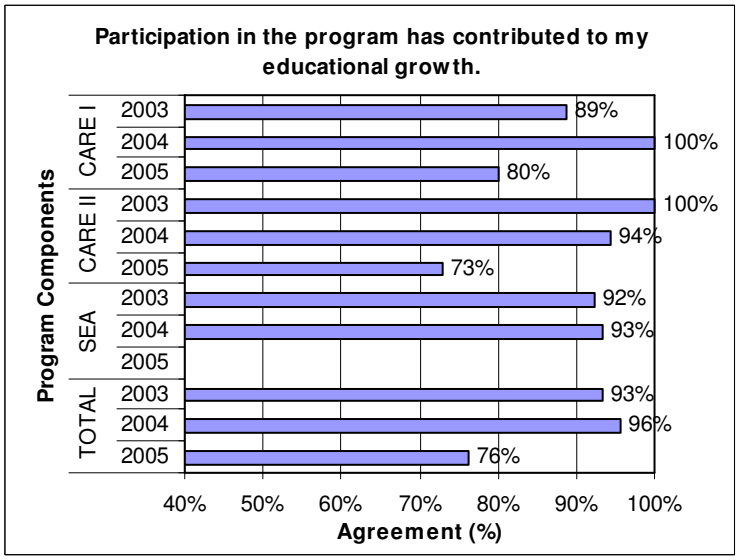

Fig. 12. CARE contribution to educational growth

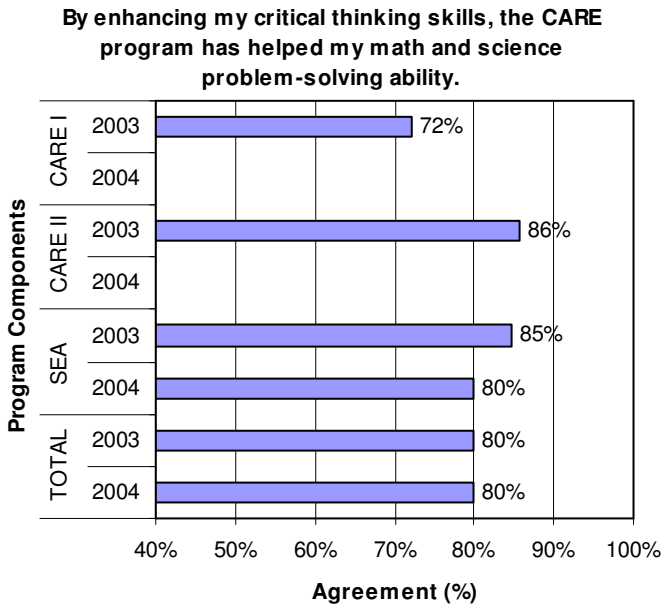

Fig. 13. CARE impact on critical thinking skills

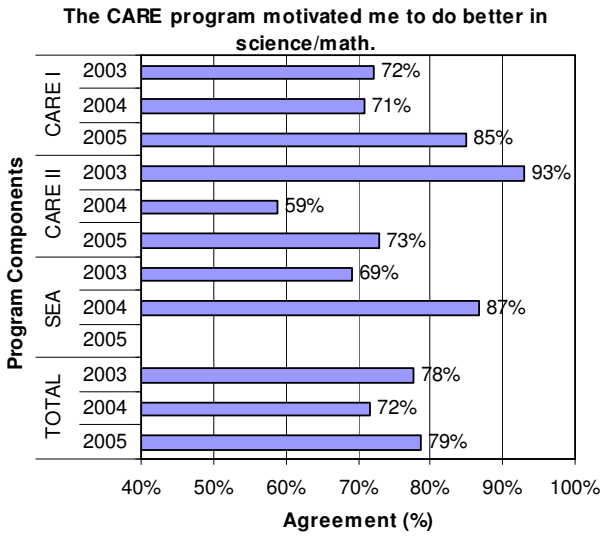

Fig. 14. CARE impact on motivation for math and science

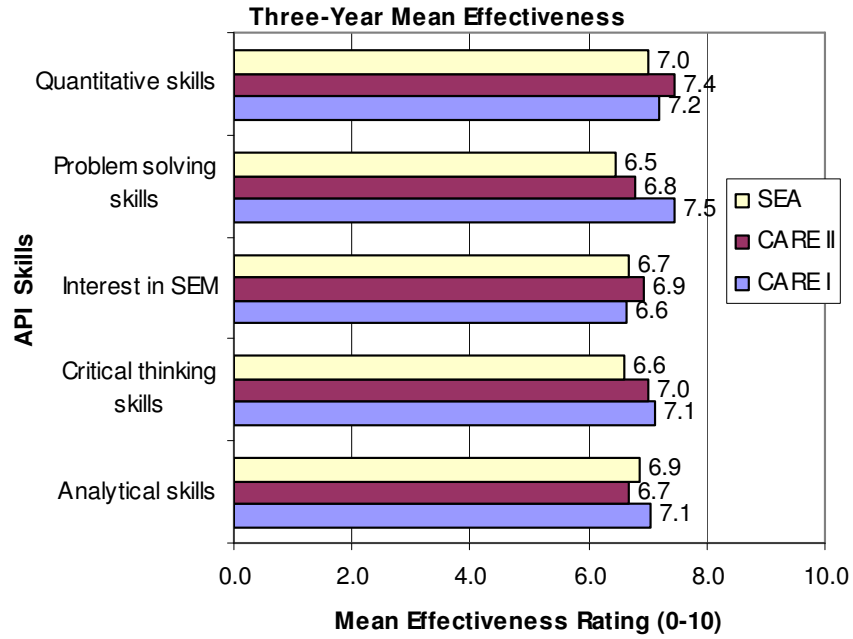

Fig. 15. Mean effectiveness of CARE and SEA on improving the academic impact factors in three program years

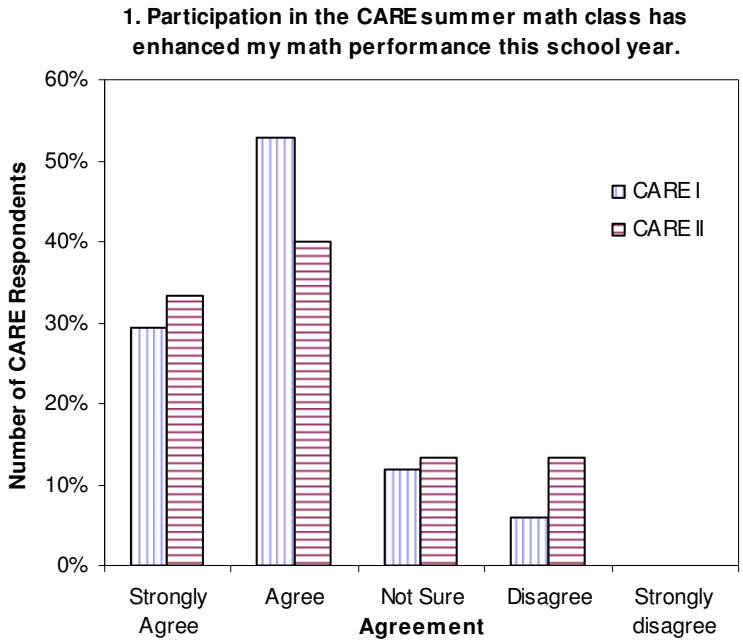

Fig. 16. Follow up of CARE students to assess impact on continued performance in high school math course

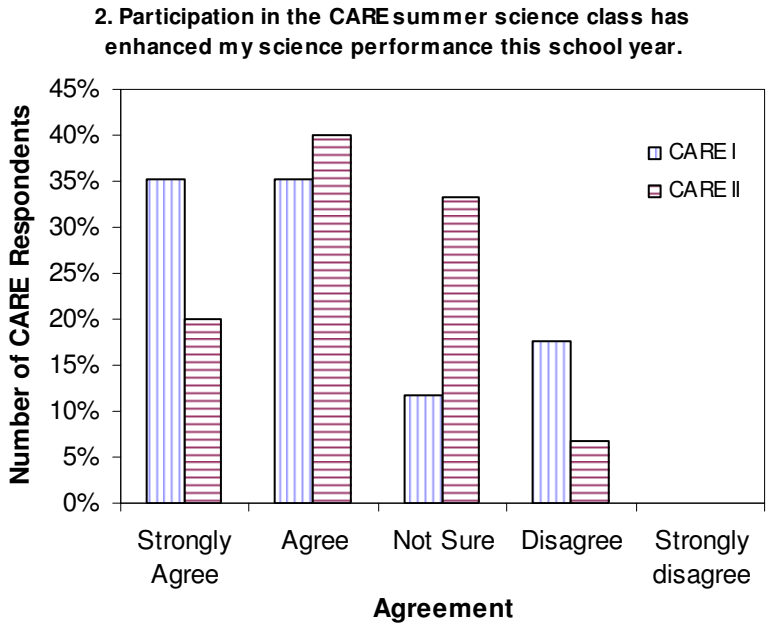

Fig. 17. Follow up of CARE students to assess impact on continued performance in high school science courses

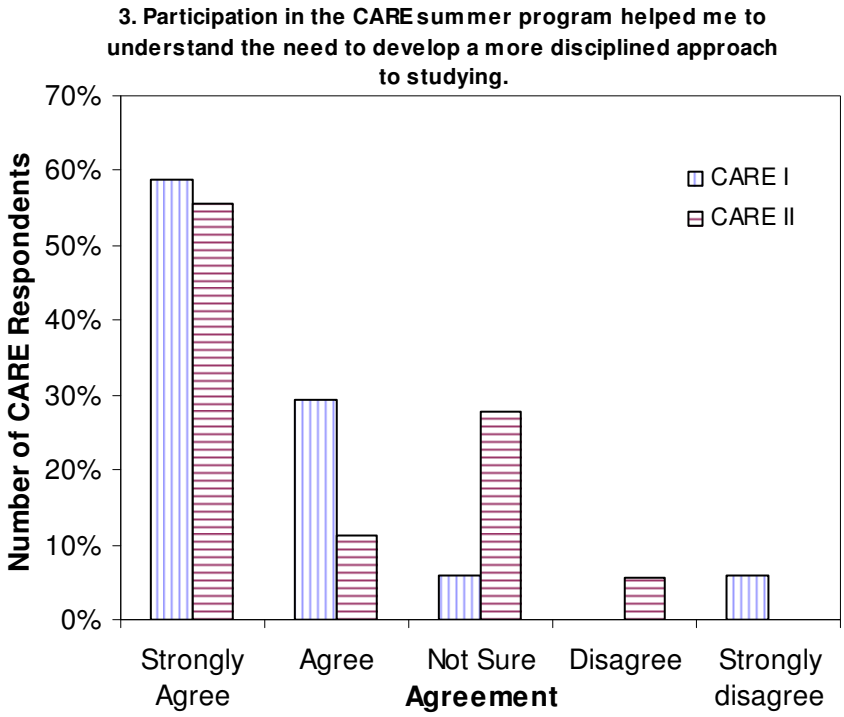

Fig. 18. Follow up of CARE students to assess impact on study skills and time management Continued performance in high school

Table 1. Three-year summary of agreement percentages

Category	Aspect	Agreement Percent
Instructors	The instructor respected students	90%
	The instructor was knowledgeable in the subject matter	89%
	The instructor was well prepared for each class	88%
	The instructor encouraged and answered questions in class	86%
	The instructor encouraged student participation and discussion	79%
	The instructor was challenging and stimulating	71%
Class logistics	Quality material was provided for the class	82%
	Class materials were presented in an orderly and understandable manner	80%
	The pace of instruction was appropriate	79%
	Test and examinations for the class were relevant to class materials	73%
Career growth	The class contributed to my educational growth	80%
	The concepts learned will be useful in my college career	80%
	Average of all aspects	82%

Overall, participants rated aspects of instructor performance more highly than aspects related to class logistics or career growth

Table 2. Year-to-year comparison of agreement percentages

Aspect	2003	2004	2005	Change 2003-04	Change, 2004-05
1. Class materials were presented in an orderly and understandable manner	86%	74%	79%	-11%	+5%
2. The pace of instruction was appropriate	85%	72%	77%	-13%	+5%
3. The instructor was knowledgeable in the subject matter	91%	84%	91%	-6%	+7%
4. The instructor was well prepared for each class	89%	85%	90%	-5%	+5%
5. The instructor respected students	94%	88%	88%	-5%	
6. Quality material was provided for the class	88%	79%	79%	-9%	
7. The class contributed to my educational growth	82%	84%	76%		-9%
8. The concepts learned will be useful in my college career	86%	83%	72%		-11%
9. Test and examinations for the class were relevant to class materials	78%	78%	80%		
10. The instructor encouraged and answered questions in class	88%	85%	85%		
11. The instructor encouraged student participation and discussion	79%	78%	81%		
12. The instructor was challenging and stimulating	72%	70%	71%		
13. Class materials were presented in an orderly and understandable manner	86%	74%	79%	-11%	+5%
14. The pace of instruction was appropriate	85%	72%	77%	-13%	+5%
15. The instructor was knowledgeable in the subject matter	91%	84%	91%	-6%	+7%
16. The instructor was well prepared for each class	89%	85%	90%	-5%	+5%
17. The instructor respected students	94%	88%	88%	-5%	
18. Quality material was provided for the class	88%	79%	79%	-9%	
19. The class contributed to my educational growth	82%	84%	76%		-9%
20. The concepts learned will be useful in my college career	86%	83%	72%		-11%
21. Test and examinations for the class were relevant to class materials	78%	78%	80%		
22. The instructor encouraged and answered questions in class	88%	85%	85%		
23. The instructor encouraged student participation and discussion	79%	78%	81%		
24. The instructor was challenging and stimulating	72%	70%	71%		

* Differences from previous year of 5 percentage points or more only are noted.

Table 3. Summary of agreement percentages for all participants by year

CARE Impact Survey	Agreement % 2003	2004	2005	Change 2003-2004	Change 2004-2005
1. The CARE program helped prepare me for the upcoming school year.	96%	96%	83%		**-13%**
2. Participation in the program has contributed to my educational growth.	94%	96%	77%		**-19%**
3. Tests, examinations, and other assignments exposed me to challenging applications or extensions of the course content.	89%	89%	71%		**-18%**
4. Participating in the program has reinforced my problem-solving skills in math and science.	89%	75%	72%	**-14%**	
5. Rate the overall effectiveness of the program "good" to "excellent"	80%	85%	57%	**+5%**	**-28%**
6. The CARE program has enhanced my critical thinking skills.	80%	77%	60%		**-17%**
7. The CARE program motivated me to do better in science and math.	77%	70%		**-7%**	
8. Using a graphical calculator has helped my understanding of lecture	76%	83%	59%	**+7%**	

	materials.					
9.	Hands-on experience helped my understanding of lecture material.	71%	83%	69%	**+12%**	**-14%**
10.	The CARE program helped me overcome my initial difficulties	64%	62%	96%		**+34%**
11.	The collaborative learning strategies helped me understand math and science better.	58%	69%	59%	**+11%**	**-10%**
12.	The CARE program has helped me feel good when I solve a math/ science problem.	55%	51%	50%	**+5%**	
13.	The level of instruction was too difficult for my preparation and ability.	13%	32%	7%	**+19%**	**-25%**
14.	The CARE program helped prepare me for the upcoming school year.	96%	96%	83%		**-13%**
15.	Participation in the program has contributed to my educational growth.	94%	96%	77%		**-19%**
16.	Tests, examinations, and other assignments exposed me to challenging applications or extensions of the course content.	89%	89%	71%		**-18%**
17.	Participating in the program has reinforced my problem-solving skills in math and science.	89%	75%	72%	**-14%**	
18.	Rate the overall effectiveness of the program "good" to "excellent"	80%	85%	57%	**+5%**	**-28%**
19.	The CARE program has enhanced my critical thinking skills.	80%	77%	60%		**-17%**
20.	The CARE program motivated me to do better in science and math.	77%	70%		**-7%**	
21.	Using a graphical calculator has helped my understanding of lecture materials.	76%	83%	59%	**+7%**	
22.	Hands-on experience helped my understanding of lecture material.	71%	83%	69%	**+12%**	**-14%**
23.	The CARE program helped me overcome my initial difficulties	64%	62%	96%		**+34%**
24.	The collaborative learning strategies helped me understand math and science better.	58%	69%	59%	**+11%**	**-10%**
25.	The CARE program has helped me feel good when I solve a math/ science problem.	55%	51%	50%	**+5%**	
26.	The level of instruction was too difficult for my preparation and ability.	13%	32%	7%	**+19%**	**-25%**

Differences from previous year of 5 percentage points or more only are noted.