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Expanding Institutional Bonds for Teaming Up Students for the Creation of Research Environmental Projects

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Expanding Institutional Bonds for Teaming Up Students for the Creation of Research Environmental Projects

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Abstract

The purpose of this project is the bridging between California State Polytechnic University, Pomona (Cal Poly Pomona) Civil Engineering students and Pasadena City College (PCC) science students to enhance the curriculum at both institutions. While enhancing the curriculum, the project seeks to improve the retention of both Cal Poly Pomona and PCC students, and to facilitate the transfer of PCC students to Cal Poly Pomona. Indirectly, the project promotes graduate school opportunities and lifelong learning in an inter-institutional disciplinary environment.

One of the main ideas behind this project is the development of teams composed of both PCC students and Cal Poly Pomona students. These student teams work on the design of natural treatment systems to remediate contaminated surface water streams. They are mentored in their research by Cal Poly Pomona and PCC faculty members. Cal Poly Pomona used the peer mentor-learning process by assigning senior student mentors to the untrained student groups. Senior student mentors provided support to their mentees while conducting experimental work in the lab, while analyzing data, and during poster and research report preparation.

Several courses were offered at both institutions to develop the collaborative approach. Faculty members in both institutions worked together on the development of a platform to foster student interaction through the use of fieldtrips and social media. This novel approach boosted student involvement, and allowed sustained collaboration among students interested in multiple disciplines (engineering, biology, biomedical sciences, pharmaceutical sciences, health, etc.). The end result is a project with multi-tiered benefits: the strengthening of inter-institutional bonds between PCC and Cal Poly Pomona, the creation of a pathway for students to transfer from PCC to Cal Poly Pomona, the training of undergraduate students with basic research skills, and the early fostering of both inter-institutional interactions and graduate studies interests. All of these benefits are achieved in an environment that is inviting and engaging for young students, while at the same time fulfills curricular requirements.

Background

The literature is rich in studies that have demonstrated the effectiveness of research as a learning tool at the undergraduate level [1,2,3,4,5,6,7]. The project detailed in this paper uses an innovative instructional method by which teaching and research are integrated to enhance students' learning experiences at both Cal Poly Pomona and PCC. The integration provides students at both institutions with the opportunity to acquire research skills and collaborate with students from

other disciplines (engineering or science) while learning about graduate school and career opportunities.

Active learning has been identified as one of the most effective pedagogical techniques to engage undergraduate students in the classroom [6,7]. More specifically, active learning involving research projects in the classroom has been widely supported as an effective pedagogical technique [3, 4,]. The Council on Undergraduate Research (CUR) has advocated the transformation of the curriculum in undergraduate teaching institutions from a typical lecture-based setup into an inquiry-based or research-based education. Undergraduate research experiences have been identified as a powerful way to enhance student learning and to develop critical thinking. Past studies have reported the following as common characteristics of successful curricula that have incorporated undergraduate research experiences: 1) reading of relevant literature, 2) working with a mentor or learning community (peer, faculty or industry professional), 3) working independently, 4) opportunity to actively participate in the experimental design, 5) opportunity to present/communicate the results of the work, 6) appropriate facilities and spaces to conduct the work, 7) faculty availability for consultation and career advice, and 8) promotion of lifelong learning and self-directed learning[8,9].

High impact teaching practices like problem-based learning and cooperative learning have been broadly investigated [10, 11, 12, 13]. Problem-based learning helps students gain problem-solving skills, motivates students to engage with problems that have more than one solution, promotes effective collaboration among students, and allows students to extrapolate their knowledge and skills to novel situations [12]. Learners become actively engaged in constructing their own knowledge, and the teacher facilitates the collaborative learning experience via an open-ended questioning process [10, 12, 8].

Mentoring is very commonly used in research programs to transfer knowledge, technical skills, and good research practices (e.g. safety and quality control practices). Transfer of knowledge and experiences can occur from faculty to graduate or undergraduate students, graduate to undergraduate students, and from experienced undergraduate to inexperienced undergraduate students [14, 15, 16, 17]. Peer mentors provide experiential knowledge and support the development of research skills through a working relationship that exists both within and outside of the research environment. Important characteristics of a mentor are interest toward the mentee and interest in supporting the mentee's learning process, positive personality traits (compassion, care, etc.), and knowledge and organization [14, 17]. Development of a strong, structured community facilitates the establishment of a good learning environment conducive to the success (retention, motivation, graduation, pursuit of higher education, etc.) of the mentees [15].

Finally, the literature is rich in reports of effective academic models that allow curricular/program development while enhancing faculty scholarly work. Such models, particularly in primarily undergraduate teaching institutions, represent sustainable solutions for continuous faculty development while providing meaningful learning experiences to undergraduate students [1, 2, 5]. The proposed project employs a dual function system which provides students with a research-based experience developed in a strong community, while contributing to the instructors' research and scholarly efforts at both Cal Poly Pomona and Pasadena City College.

Introduction

Pasadena City College. The Pasadena City College (PCC) School of Science and Math provides students with access to a full range of STEM courses. Courses are offered in science disciplines including Physics, Anatomy, Astronomy, Biology, Physiology, Geography, Geology, Microbiology, Physical Sciences, and Chemistry. PCC is a two-year institution with a history of rigor in its science curricula, through which students not only learn facts, but learn how to think critically and generate novel outcomes. PCC science students engage in active learning, particularly in PCC's many laboratory-centered courses. PCC received a five-year Department of Education Title III grant for the purposes of revamping the STEM curriculum, increasing student retention, boosting success, and promoting student transfer to four-year colleges. In particular, grant funds have been directed towards enhanced educational opportunities in environmental biology through PCC's eSTEM program. Through eSTEM, students have access to a complete support infrastructure that includes active learning, mentoring, outreach, and career guidance. The eSTEM center promotes doing real science in the classroom, to which end grant funds have been used to introduce current methods and technologies from electron microscopy to nanotechnology to DNA sequencing into PCC science courses. PCC participants future professional pathways were reported to be in the following STEM areas: medicine, pharmacy, biology, bioengineering, forensics, biochemistry, horticulture, ecology, physical therapy, environmental sciences, and toxicology; which generated a multidisciplinary environment of the student teams.

Cal Poly Pomona. To magnify its efforts of providing diverse and multidisciplinary academic experiences, PCC partnered with the Civil Engineering (CE) Department at Cal Poly Pomona. The Cal Poly Pomona campus is located northeast of Los Angeles. The campus is attended by traditional (undergraduate and graduate full-time) and non-traditional (part-time students that work over 35 hours per week, financially independent, with dependents, veterans, etc.) students. The CE Department student population for 2009, 2010 & 2011 included 34% White, 27% Asian, 28% Hispanic/Latino, 3% Black/African American, and 1% Native Hawaiian students, with 7% not specified (Cal Poly Pomona Data Warehouse). Thus, the CE department has a very diverse academic environment. The CE department is one of the largest CE programs in US [18], with approximately 1,200 undergraduate students and 120 MSCE graduate students (Cal Poly Pomona Data Warehouse).

Cal Poly Pomona prides itself on community-based learning, in which students interact with the surrounding community as they learn. Students graduating from Cal Poly Pomona's programs are prepared to be professionals. Cal Poly Pomona campus goals include: 1) the advancement of the teaching and scholarly work of faculty members to enhance student learning experiences, 2) enhancing student success, 3) the promotion of collaborative work across disciplines to strengthen learning-centered education, and 4) the promotion of environmental sustainability through the recognition of responsibilities to the global community. The program proposed by PCC unified the mission and teaching philosophies at both institutions, and strongly supported the Cal Poly Pomona learn-by-doing philosophy through the creation of inter-institutional teams of faculty and students.

Research objectives

The purpose of the project is the enhancement of the curriculum at both institutions through a collaborative, academic experience based around practical solutions to real world problems. Furthermore, the project intended to facilitate student transfer from PCC to Cal Poly Pomona, and to develop interest in graduate school among all participants. At Cal Poly Pomona, students were trained to engage in different research activities. At PCC, students were mentored by Cal Poly Pomona students to evaluate the solution of an environmental problem. The inter-institution partnership has allowed the development of different environmental research projects in the course of two years.

The partnership project had the following objectives:

- Evaluation of the effectiveness of the new curriculum.
- Evaluation of student performance while working in an inter-institutional team.
- Evaluation of the impact of the research experience on student interest to pursue a higher degree.
- Evaluation of PCC student interest in transferring to Cal Poly Pomona.

Methodology

The method used to establish the academic relationship between Cal Poly Pomona and PCC students is shown in Figure 1. The structure is team oriented. During the two years of interaction, several teams of Cal Poly Pomona engineers were selected based on their interest of developing research skills. The first engineering team cohort had an undergraduate student with previous extensive research experience as peer mentor. At PCC, work on the environmental problem was included as a curriculum requirement for all students in the selected courses. Social media was used to facilitate and enhance student interaction during the project.

Curriculum at Cal Poly Pomona. A new senior level course was created (CE 400- Research Experience for Undergraduates). This course provided up to 4 units of required major electives to CE students participating in the project. This course fulfilled ABET (a) through (g), (i) and (j) student learning outcomes required for engineering programs. In addition, the course provided research skills training activities (one month in advance before the interaction with PCC), and time for the students to meet and work on developing tools to collaborate with PCC students. In the first term of the collaboration, the Cal Poly Pomona team consisted of nine inexperienced undergraduate students, one inexperienced transfer student (transferred from PCC at the start of the academic year), one experienced senior student (peer mentor for the inexperienced engineering students), and two engineering CE faculty members. The following workshops were part of the CE 400 course: hypothesis development, experimental design, reading club, poster, and paper and oral presentation preparation. As the project developed, the inexperienced participants became peer-mentors in consecutive terms. Through this interaction, a total of 17 CE undergraduate students have been trained with basic research skills and peer mentoring skills. Out of the 17 Cal Poly Pomona student participants to date, 65 % were female and 35% male, with 12% Hispanic/Latino, 45% Asian, 24 % White, 6% Black/African American, and 12% others.

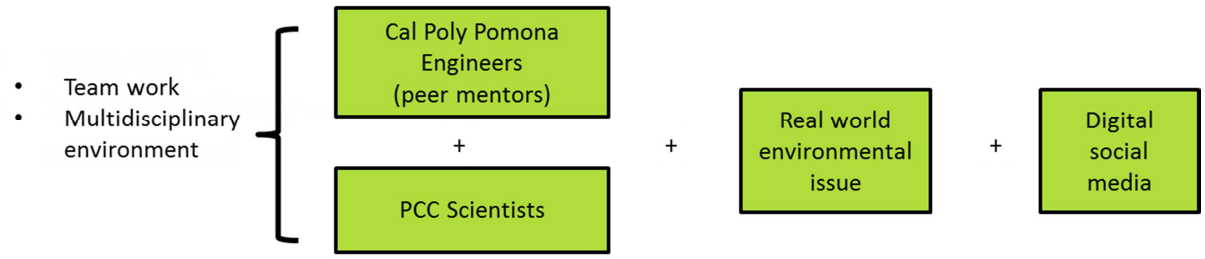

Figure 1. Method used to establish the academic relationship between Cal Poly Pomona and Pasadena City College.

Curriculum at Pasadena City College. Introduction to Environmental Science (ENVS 1) and Diversity of Life on Earth: Structure, Function, and Ecology (BIOL 10B) are PCC Biology Department project-based courses that use active learning to teach scientific methods and concepts. ENVS 1 is a non-majors general education course, while BIOL 10B is the second course in a series of three courses that are required for all biology majors. The Cal Poly Pomona collaboration is the first inter-institution collaboration that has been integrated into either of these courses. The PCC team for the past two years has consisted of fifty PCC students enrolled in two sections of ENVS 1 courses (Fall 2013), 23 students enrolled in the Spring 2014 BIO 10B course, 26 students enrolled in each of two Fall 2014 BIO 10B sections, and 27 students enrolled in a Spring 2015 BIO 10B section. Ethnic demographics of the 102 Biol 10B student participants are 4% Black/African American, 12% White, 49% Asian/Pacific Islander, 18% Hispanic/Latin, 17% Other; 55.9% of participants are women. In advisory roles are two biology faculty members. Planning and financial support is administered by the director of the eSTEM center.

Common features of curriculum at both institutions. Cal Poly Pomona and Pasadena City College designed their courses curricula to include 1) research skills training, and 2) interaction between students from both institutions. The curriculum was designed to provide a challenging but manageable learning environment that promoted critical and creative thinking. The mechanism used for the integration of research training activities and student interaction activities is shown in Figure 2.

1) **Training of research skills**. The curricula in both institutions included research skills such as review and discussion of relevant literature and learning to cite references; laboratory safety training and safety practices; system design and implementation; water sample collection and testing; data analysis; manuscript, poster and PowerPoint preparation; and final results presentation (oral or online). In addition to the manuscript, poster, and oral presentation, assessment of analysis and deduction skills gained by Cal Poly Pomona engineering students after approximately 4 months of training was supported via a test that required the analysis of portions of research results extracted from different non-familiar references (results not shown in this manuscript). Pasadena City College evaluated the acquired skill development via the regular course final exam and either a final online poster presentation (ENVS 1) or final oral colloquium presentations of the project results (BIOL 10B).

2) **Student interaction**. Every semester, student interaction revolved around the design and construction of a natural treatment system that had the objective of improving surface water quality. The engineering team supported the science students with the hydraulic and treatment process design, while PCC scientists constructed the devices and evaluated the biological inputs/outputs in the system (picked biological seeds, plate counted bacteria, conducted DNA sequencing). Similar experimental set-ups were operated at both institutions. Cal Poly Pomona engineers provided support with system operation and water sample analysis. Student interaction was achieved by using:
   (a) Initial in-person two-hour meetings. Every semester, to break the ice and engage PCC and Cal Poly Pomona students with the collaborative work, initial meetings were hosted at Cal Poly Pomona. PCC students and the professor(s) visited the campus and had the opportunity of touring the engineering laboratory facilities. The initial meetings allowed all students to get to know each other and create stronger bonds, which supported their work and communication dynamics throughout the semester. Initial meetings were also used to present results from past research experiences at Cal Poly Pomona, to form student teams, and to have the opportunity of discussing problems, potential solutions, and feasibility (practical, construction, financial, etc.).
   (b) Fieldtrips. Students from both institutions were taken to field locations to observe and evaluate sites affected by the environmental problem assigned by the instructors. Students also visited field sites to observe current environmental engineering practices used to mitigate similar environmental problems. Participation in the required class field experience allowed student interaction. Differences in class schedules presented a significant challenge in arranging a single field trip.
   (c) Social Media. Social media was used to facilitate and enhance student interaction. Since PCC is located 26 miles west from Cal Poly Pomona, and travel time between institutions is frequently increased by the constant traffic of the LA/Pasadena area, the use of social media facilitated continuous, frequent and instantaneous interaction between engineers and scientists. Social media was used to share questions/answers regarding the operation of the treatment systems, to share short manuals developed to aid scientists with pump operation, to share relevant current news regarding the topic under investigation, to share diagrams and preliminary proposals of the designs, to share data and results, and to share project progress, among other communications. The instructors involved in the project were invited to be participants of the social media sites.
   (d) Project Implementation. The final design implementation occurred at Pasadena City College. Half-way through the semester, Cal Poly Pomona engineering students and one professor traveled to PCC. Engineers worked with the scientists on the implementation of the final design of the water treatment system. Engineering students explained the hydraulic characteristics of the system (flow rate theoretical calculation and actual measurement, total head, losses, size of tubing, etc.) to the PCC students. Implementation activities ended when the treatment system was up and running and ready for the scientists to start the experiment.
   (e) Final in-person meeting. The final student interactions took place at the Cal Poly Pomona campus, where PCC students shared the results of their one-semester experimental work to the engineering students and faculty. In addition, PCC students were informed about the process to transfer to Cal Poly Pomona. The final presentation was a portion of the PCC students' final course grades.

Figure 2. Integration of the research training activities and the student interaction activities.

Project results

The results of the project were evaluated by comparing them with the courses outcomes. The common outcomes of the course curriculum at both institutions were:
Students will:

- Read relevant literature and use of information to aid in the experimental design.
- Design experiments following the scientific method.
- Collect samples and conduct water analysis.
- Analyze data collected and explain results.
- Prepare written reports following research conventions.
- Prepare posters to showcase the results of the project.
- Effectively communicate orally results of an experiment.

Posters. The first semester engineering and science students were required to present their results in poster format, via an online poster presentation (http://posters.pccstem.org). The online interaction allowed the students from Cal Poly Pomona and PCC to see each team's work within a period of one week. Students interacted with their peers by leaving written comments and/or questions for each team. The online poster setup allowed participation by multiple students and faculty, which promoted further thinking regarding the results presented by each team (Figure 3). The online poster presentation increased the time for interaction and time for students to ask/respond to questions. However, students' comments indicated that there were limited interactions among students from both institutions. Consequently, instructors determined that it was important to culminate the collaborative experience with a final in-person meeting. Thus, the following semesters the project experience culminated with oral presentations, where all the students had the opportunity to ask questions directly to each team.

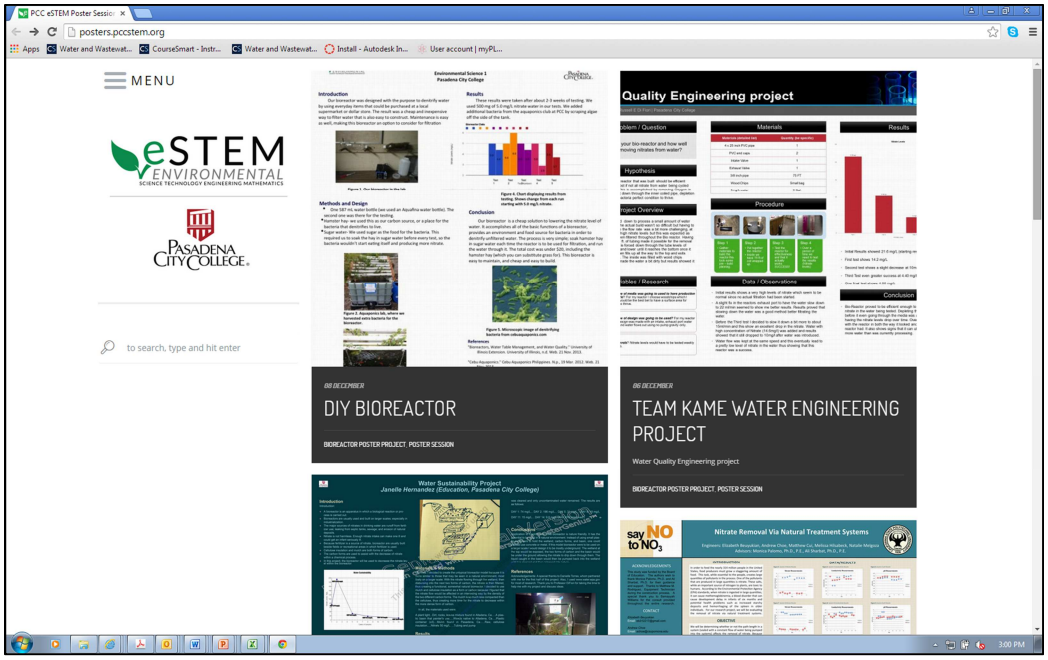

Figure 3. Online poster presentation, fall 2013 http://posters.pccstem.org

In the first semester, all teams were required to produce a poster. The objectives were to demonstrate the ability to communicate ideas in an organized fashion, and to demonstrate that students could use the scientific method. Figure 4 shows two examples of the posters produced during fall 2013. Most posters had good use of graphics that facilitated the communication of the project idea. However, some posters were heavy on text, which demonstrated the need for further development of graphical communication skills to prepare effective technical posters. In most cases, posters followed the scientific method steps, which helped to clearly demonstrate the progress of the project. Some teams used the term "objective(s)" to describe the tested experimental hypothesis. However, it was common for students to omit the tested hypothesis as part of the poster content. Overall, the poster presentation demonstrated that all student teams were familiar with the scientific method steps, and that while their technical communication skills were basically effective, these skills were at different stages of development.

The discussion generated during the online poster presentation demonstrated that 1) students were motivated and excited to share their work with their peers and faculty, 2) students were excited to have the opportunity to ask questions of their peers, and 3) the comments section promoted the critical thinking process by allowing students to formulate questions or to provide comments to their peers. Each poster had a different number of comments, and each one generated positive educational discussion. Student comments were evaluated qualitatively and the following characteristics were recurrently identified: a) familiarity with the problem and relevant literature, 2) student understanding of proposed solution, and identification of implementation issues or potential benefits, 3) capacity to accept that there are many solutions for any given problem, and 4) capacity of communicating ideas to peers. Overall, it was observed that students did better in the problem identification, and with demonstrating their awareness that a single problem can have multiple solutions. All posters and associated comments can be accessed at http://posters.pccstem.org.

Figure 4. Sample posters product of the collaborative project experience (fall 2013)

Papers

Cal Poly Pomona Students. Engineering students were required to prepare a manuscript to disseminate the results of their research work. The CE 400 class provided students with sessions on 1) how to prepare a research manuscript, 2) how to properly cite sources of information, 3) and how to write an abstract. After 4 months of training, the students enrolled in the course were required to individually prepare a manuscript to report research results. Student manuscripts were assessed with a rubric developed to weigh the progress of students' abilities to cite sources, to organize data and present it in a concise manner, effective use of the space, and the level of discussion & analysis (supporting their results with past studies or known theories). The rubric ranked the abilities from 1 to 5, where the ranking levels from lowest to highest were defined as very poor, poor, fair, good, and very good; or much less than expected, less than expected, matched expectations, exceeded expectations, and greatly exceeded expectations. The average value of the results obtained from grouping and weighing the scores by the value associated with the respective levels is given in Table 1. Standard deviation of each category suggested that while the results for the fall 2013 were not significantly different from the ones observed in spring 2014, they were significantly different from those observed in fall 2014.

Preparation of a research manuscript is a challenging experience that requires a lot of training and practice. In fall 2013, nine of the ten engineering students were able to individually generate a full research manuscript. However, skill level varied significantly. The results in Table 1 indicate that overall, all papers matched expectations, with most values above 3.0. All manuscripts included reference lists, but the sources of information were not consistently cited, which is reflected in the score (3.33) in the analysis level. Analysis of results could have been strengthened by the use of existing knowledge to support or to make inferences from the findings. Most manuscripts were prepared using research journal format and standards. Manuscripts showed that student authors followed the scientific method (3.56), and that papers could have a more efficient use of the space (3.22). The data organization and effectiveness of figures to report results (3.78) indicated that the performance of the first cohort of students matched expectations. It is important to note that there was one individual scored at the "much less than expected" level in most of the rubric categories, while two other students consistently scored at the greatly exceeded expectations. Nine of the ten students enrolled in the fall 2013 course were able to develop the desired skills to different degrees. For the study, students' background or family data was not collected; however, towards the end of the course, one of the students that scored consistently in the "greatly exceeded expectations" reported that one of their parents had a Ph.D. degree. Thus, the ability of this student to prepare research manuscripts might have been previously advanced and not a product of the course experience.

Table 1. Results from manuscript evaluation.

Paper Evaluation Rubric	Individual Manuscript Score Fall 2013	Group Manuscript 1 Score Spring 2014	Group Manuscript 2 Score Fall 2014
References included	4.22	5.00	5.00
References properly cited	3.00	3.50	3.00
Followed scientific method	3.56	5.00	5.00
Data organized and data concisely shown	3.78	3.50	4.00
Effective use of space	3.22	5.00	5.00
Effectiveness of figures to demonstrated the point	3.78	4.00	4.00
Clarity of discussion	3.44	3.00	4.00
Analysis Level	3.33	3.50	4.00
Average	3.54	4.06	4.25
Standard Deviation	0.38	0.82	0.71

In the following terms (spring 2014 and fall 2014) the engineering students prepared two different group manuscripts, Group 1 in spring 2014, and Group 2 in fall 2014. The five students participating in Group 1 were peer mentors of the three students in Group 2. None of the students

participating in spring 2014 participated in fall 2014 activities or manuscript preparation. Results from the manuscripts produced by Group 1 and Group 2 are also shown in Table 1. The results suggest that having multiple authors improved the effective use of space and the comprehensive list of references. In addition, data organization and concise presentation of results (4.0) improved significantly in fall 2014 when a co-author model was used. The results for proper citation of sources and analysis level skills (which showed an improvement compared to individual papers) clearly indicated that students needed to continue revising the manuscript guided by an experienced mentor, or that they needed to continue the technical writing experience to further develop their skills. Overall, after the paper preparation experience, the majority of the students had a "matched expectations" score and they were ready to continue developing writing skills in future experiences.

Indirect assessment

At the conclusion of the experience as part of the required course assignments, all students completed an anonymous SurveyMonkey questioner. The survey collected information about student experiences for students enrolled in the Cal Poly Pomona CE 400 course or in one of the PCC courses. At both institutions, the curriculum had common learning elements important for any student involved in research activities. The survey included questions to learn about student experiences with the project, and their interest in higher education. Cal Poly Pomona students also responded to questions related to their experience as peer mentors.

1) Curriculum effectiveness.

Evaluation of student work showed evidence of the effectiveness of the curriculum. Through the online poster presentation, manuscript preparation, and presentations prepared and shared with peers and faculty from both students, it was evident that the outcomes of the class were achieved (see Project Results section). The survey results allowed instructors to learn to what extent students thought that the course outcomes were achieved. Table 2 shows the topics that students considered being included in the course curriculum.

At least 50% of the PCC Students responses indicated that social activities, team building dynamics and guidance to prepare data reports (poster, paper, or orally) were part of the curriculum. The graduate school application discussion was not identified as an evident component of the curriculum (only 2 to 8% of respondents identified it as part of the curriculum). This can be attributed to the emphasis of preparing community college students to transfer to 4-year colleges instead of preparing them for graduate school. Ethics and safety training were not identified as significant in course content. PCC results indicated that from the first term to the second, there was an increase in the number of students that identified most of the topics in the list as part of the course content. About 75% of the Cal Poly Pomona students identified safety training, team building dynamics, and guidance to report results as the most common topics in the course content. Ethics, seminars, visiting scientists, and graduate applications were not identified as significant aspects of the Cal Poly Pomona curriculum. Overall, survey results indicated that students from both institutions shared similar opinions regarding the topics covered in the course.

Table 2. Topics reported as part of the curriculum

The course curriculum contained the following activities (Check as many as apply)	Cal Poly Pomona fall 13	Cal Poly Pomona fall 14	PCC spring 2014	PCC fall 2014
Answer Options	Response Percent			
Safety training	100%	100%	17%	47%
Ethics discussion	25%	0%	17%	47%
Social Activities	67%	100%	65%	66%
Team building dynamics	92%	100%	65%	87%
Seminars or visiting scientists	58%	0%	52%	68%
Proposal Writing	58%	100%	41%	81%
Grad school application seminar	8%	0%	2%	4%
Guidance for report writing, poster preparation and oral communication	75%	100%	63%	83%
Answered question	13	3	46	53
Skipped question	0	0	2	5

The skills that students reported as gained via the course experience are shown in Table 3. At least 52% of the students expressed that they acquired all skills listed in Table 3. For both Cal Poly Pomona and PCC, a higher percentage of students reported acquisition of the majority of the skills increased in the second term (fall 2014). At least 52 % of students indicated that they had acquired skills of becoming independent learners and making connections to courses taken in the past. The number of students reporting improvement of technical written skills varied widely from 59% to 83% of participants. At least 65% of all participants thought that they learned how to use scientific literature. Manuscripts prepared by the engineers provided direct evidence for this skill. However, evaluation of the manuscripts indicated that the skill was not fully developed and more practice was necessary to improve the quality of the analysis. Thus, student opinions supported the results of the direct assessment of student work. The course curriculum was effective in introducing the desired research skills (see Project Results section), and students developed the skills to different levels, most likely due to different past experiences.

2) Inter-institutional experience

In general, the majority of the students agreed or strongly agreed (57 to 89 %) that working with students from both institutions was beneficial for project completion (Table 4). Twenty five percent of engineering students disagreed that the experience with science students was beneficial. It is unclear if the fact that engineering students were assigned to be peer mentors at the start of the project could have affected their view of the potential gains of working with scientists. In fall 2014, 89% of the PCC students agreed that the work with the engineers supported the project design, thus there was a significant increase on the number of students agreeing with this statement compared to fall 13_spring 14 (57%). Survey results reported by PCC students in fall 13_spring 14 were used to refocus the mentoring work done with the engineering students. Thus, in the second term, the new objective was to improve collaboration and increase the number of students that agreed on the value of the inter-institutional work of the

project. In fall 2013, Cal Poly Pomona engineering students had the peer mentor role, and at the same time they were introduced to and trained in basic research skills. In spring 2014, and fall 2014, engineering students were focused only on being peer-mentors, and thus had a stronger interaction with PCC students.

Table 3. Skills reported students reported as gained through the course experience

By participating in the undergraduate research project I have...(Check as many apply)	Cal Poly Pomona fall 13	Cal Poly Pomona fall 14	PCC fall 13_ Spring 14	PCC fall 14
Answer Options	Response Percent			
Learned an advanced topic in -depth.	67%	67%	65%	76%
Became an independent learner.	67%	67%	65%	53%
Applied knowledge to a real situation.	83%	67%	65%	89%
Developed experience in water analysis testing.	83%	100%	65%	85%
Learned to think independently about solutions for complex problems.	83%	100%	65%	66%
Learned to analyze data.	100%	100%	65%	91%
Improved technical writing skills.	83%	67%	65%	59%
Improved technical oral communication skills.	75%	100%	65%	79%
Learned what actual scientific research is about.	92%	67%	65%	7%
Made connections to courses that I have taken in the past.	58%	67%	65%	53%
Learned that research ideas are built on previous studies.	92%	100%	65%	74%
Learned to use scientific literature.	67%	100%	65%	76%
Answered question	12	3	46	53
Skipped question	1	0	2	5

Table 4. Value of the inter-institutional disciplinary experience

Working with_____ defining the solution of an environmental problem provided valuable information to design the experimental set up.	science students (fall 2013 Cal Poly Pomona responses)	engineering students (fall13_spring14 PCC responses)	engineering students (fall 2014 PCC responses)
Answer Options	Response Percent		
Completely agree	8%	21%	42%
Agree	50%	36%	47%
Not sure	17%	15%	11%
Disagree	25%	21%	0%
Completely disagree	0%	6%	0%
Answered question	12	47	53
Skipped question	1	1	5

3) Interest in graduate school

Between 11 and 25% of the students expressed that they were not sure if the course experience had awakened their interest in attending graduate school in the future (Table 5). However, about 60% of the students from both institutions agreed that the experience with the project had created an interest in attending graduate school. Thus, indirect evaluation indicated that the course research experience enhanced student interest in graduate school. More than 57% of PCC students reported that they felt equipped with basic research skills that resulted from collaboration with Cal Poly Pomona students (Table 6). However, about 26% of students enrolled in the PCC courses felt unsure if their skills were strong enough for graduate school.

Table 5. Interest in graduate school.

After the Cal Poly Pomona_PCC research experience I am interested in pursuing graduate school in the future.	Cal Poly Pomona	PCC fall 2013_spring 2014	PCC fall 2014
Answer Options	Response Percent		
Completely agree	33%	19%	42%
Agree	42%	45%	42%
Not sure	25%	23%	11%
Disagree	0%	11%	6%
Completely disagree	0%	2%	0%
Answered question	12	47	53
Skipped question	1	1	5

Table 6. Basic research skills resulting from the experience

After the research experience at PCC (in collaboration with Cal Poly Pomona), I feel…	PCC fall 2013_spring 2014	PCC fall 2014
Answer Options	Response Percent	
equipped with enough basic research skills to attend graduate school.	57%	67%
unsure if my research skills are strong for graduate school.	30%	27%
that while I want to attend grad school, I don't want to attend a research-based program.	13%	6%
Answered question	47	53
Skipped question	1	5

4) Student transfer interest

The percentage of students expressing interest in transferring to Cal Poly Pomona (~ 15%) as a result of the experience in the course was not significantly different from those already planning on applying in the future (Table 7). At least 36% of students who took the PCC courses were not planning on transferring to Cal Poly Pomona. These results align with the fact that the majority of students enrolled in the PCC courses were interested in STEM areas other than those offered at Cal Poly Pomona (e.g., biomedical, pharmaceutical sciences, forensics, etc.).

Table 7. Interest in transferring to Cal Poly Pomona

After the research experience collaborating with Cal Poly Pomona students are you interested in transferring to Cal Poly Pomona?	PCC fall 2013_spring 2014	PCC fall 2014
Answer Options		
I have already applied.	7%	21%
Yes, in the future.	15%	15%
I am not sure.	33%	27%
No	46%	37%
Answered question	47	53
Skipped question	1	5

Conclusions

All research project objectives were directly and indirectly assessed. According to students' survey results and evaluation of the student work, the objectives of the project were met to different degrees.

Evaluation of curriculum effectiveness. Students indicated that most of the topics relevant to training of basic research skills were included in the curriculum. In addition, students reported increased confidence in their acquired research skills. These results are supported by findings from direct evaluation of student work in which manuscripts demonstrated the use of acquired research skills.

Common class topics for both Cal Poly Pomona and PCC courses were team building activities and guidance for the preparation of deliverables. Approximately ~50% of students reported that they were able to apply theory learned in past courses to analyze their data, making connections to classes taken in the past.

Evaluation of performance of students working in an inter-institutional team. Overall, 36 to 50% of the students expressed that the inter-institutional collaboration was beneficial for project completion, with larger agreement in the second round of project collaboration (Fall 2014). It is hypothesized that the increase in the percent of students agreeing could have been a result of the engineering students getting more familiar and comfortable in their role of peer-mentors and with modification of expectations as they became experienced.

Communication among Cal Poly Pomona and PCC students was not as effective as planned the first time that the collaboration was implemented, but it was significantly improved as engineering mentors developed their skills.

Evaluation of the impact of the research experience in student interest to pursue a higher degree. About 60% of the students from both institutions agreed that the experience had increased their interest of attending graduate school. It is believed that the opportunity of developing a small scale research project, with enough time to analyze and present results, had impacted students by providing them with confidence to seek more complex and challenging research situations. It was also determined that a seminar specifically targeting graduate school applications could be added to the curriculum to ensure that the students have a clear connection between the research experience in the course and the path to graduate school.

Evaluation of PCC student interest in transferring to Cal Poly Pomona. About 15% of the students enrolled in the different PCC courses could potentially transfer to Cal Poly Pomona. With the remaining percentage of PCC students interested in non-engineering, or health-related majors not offered by Cal Poly Pomona.

Lessons learned

- Improvement of communication through social media among Cal Poly Pomona and PCC students was achieved by adding it as a course requirement with a grade associated.
- Training of Cal Poly Pomona peer mentors should occur before the interaction with PCC.
- Reducing the research activities of Cal Poly Pomona peer mentors allowed them to concentrate on developing relationships with the science students rather than concentrating on the originality and operability of their own treatment system.

- The ethics topic and graduate school application should be individually introduced in focused seminars to ensure that students realize that these topics are part of the curriculum.
- Peer mentors need to have a focused seminar on the benefits of peer mentoring relationships.

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