Student Peer Teaching in Engineering Laboratory Situations

Dr. Ernest M. Kim P.E., University of San Diego

Ernest M. Kim received the B.S.E.E. from the University of Hawaii at Manoa, and M.S.E.E. and Ph.D. in Electrical Engineering from New Mexico State University. After spending ten years in industry at the then National Bureau of Standards (now NIST) in Boulder, Colorado, Burroughs Corporation (now Unisys) in San Diego, California, and TACAN Corporation in Carlsbad, California, he joined the faculty of the University of San Diego in 1990. He is currently Associate Professor of Electrical Engineering at USD, teaching primarily in the areas of analog circuits and electronics, communication systems, electromagnetic fields, and engineernig design. He and Dr. Thomas Schubert are co-authors of the electronics text, Active and Non-Linear Electronics. Dr. Kim is a Registered Professional Engineer (EE) in the State of California.

Dr. Thomas F. Schubert Jr. P.E., University of San Diego

Thomas F. Schubert, Jr. received his B.S., M.S., and Ph.D. degrees in Electrical Engineering from the University of California, Irvine, Irvine CA. He is currently Professor of Electrical Engineering at the University of San Diego, San Diego, CA, and came there as a founding member of the engineering faculty in 1987. He previously served on the electrical engineering faculty at the University of Portland, Portland OR and Portland State University, Portland OR and on the engineering staff at Hughes Aircraft Company, Los Angeles, CA. Prof. Schubert is a member of IEEE and ASEE and is a registered professional engineer in Oregon. In 2012 he received the ASEE Robert G Quinn Award for outstanding contributions in experimentation and laboratory instruction. He currently serves as the faculty advisor for the Kappa Eta chapter of Eta Kappa Nu at the University of San Diego.

Prof. Frank G Jacobitz, University of San Diego

Frank G. Jacobitz received his Diploma in physics from Georg-August Universität, Göttingen, Germany, in 1993, and the M.S. and Ph.D. degrees in mechanical engineering from the University of California, San Diego, La Jolla, in 1995 and 1998, respectively. He has been with the University of San Diego, San Diego, CA, since 2003, where he is currently a Professor of mechanical engineering. From 1998 to 2003, he was an Assistant Professor of mechanical engineering with the University of California, Riverside. Since 2006, he has also been a frequent visitor with the Laboratoire de Mécanique, Modélisation & Procédés Propres at Aix-Marseille Université, Marseille, France and he spent his sabbatical leave at this institution during the 2009/2010 academic year. His research interests include direct numerical simulations of turbulent flows with shear, rotation, and stratification, bio-fluid mechanical problems at the microscale, and engineering education topics. He currently serves as the faculty advisor to the student section of the American Society of Mechanical Engineers at the University of San Diego. He is the vice chair of the Education and Career Outreach Committee of the Division of Fluid Dynamics of the American Physical Society. He serves at the chair of the Engineering, Technology and Applied Sciences Section as well as on the Council and Executive Committee of the Pacific Division of the American Association for the Advancement of Science.

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Abstract
The impact of student peer led instructors on student learning in the skills and theory based laboratory (hands on) component of an Electric Circuits course is assessed. Each week a different team of two student Peer Assistants (PAs) presents background material concerning the week's laboratory exercise and then assists the other students in completing the exercise. By the end of the course each student will have been a PA at least once.

The PAs meet with the course instructor prior to their assigned instructional period. At this meeting, the PAs learn the necessary background theory and receive guidance on experimental and simulation techniques particular to the laboratory exercise of their assigned instructional period. The PAs then independently conduct the laboratory experiment.

After the PAs' meeting with the course instructor and their independently completed laboratory exercise, they prepare an introductory lecture on the laboratory exercise's background theory, simulation expectations, instrumentation, and expected experimental results. At the scheduled laboratory period, the PAs present to their peers. In addition, the PAs take on the primary responsibility for assisting the other students during the laboratory period.

The efficacy of using peer teaching in this setting is assessed through the use of three student surveys as well as course instructor evaluation.

I. Introduction

Although the basic premise is simple, peer teaching is a complex process by which students learn from other students. Potential benefits of peer teaching for students learning from the peers include the following:

- Many students feel more comfortable asking questions of other students, rather than of their professor
- Many students experience reduced frustration on difficult assignments
- There is more time for individualized attention

Potential benefits of peer teaching for student Peer Assistants (PAs) include the following:

- Teaching others ensures a high level of content mastery
- Students feel a sense of accomplishment
- Students gain a valuable teaching experience
- Students gain life-long learning skills

A study of peer teaching in college mathematics by Vassay [1] found that it "greatly affects the intellectual and moral values of the students, such as the ability to express their ideas, mastery of different concepts, time management, sense of responsibility, sharing, self-discipline, self-reliance, self-confidence, resourcefulness…"

Many university-level Science, Technology, Engineering and Math (STEM) subjects are experiencing a push for technologically enhanced classrooms, which increases the challenges associated with teaching these already complex courses. Laboratory courses inherently use state-of-the-art technology and methods increasing challenge to teach both theoretical foundations and use of state-of-the-art instrumentation and software. In Jaeger's [2] "ATLAS - Academic Teaching and Learning Assistants Study: The Use of Peers as 'Quality Managers' in Engineering Class Instruction," innovative options for addressing learning methods other than instructor-based pedagogy to foster either individual/solitary responsibility for learning or group-based education and to enhance student-centered learning was accomplished using dedicated peers as Quality Managers" (QMs).

Aspects of instructional scaffolding which is the intentional use of a resource for learning-enhancement purposes, can be applied solutions for bridging the gap between "actual developmental level as determined by independent problem solving" and the level of "potential development as determined through problem solving under adult guidance or in collaboration with more able peers." [2]. While instructional scaffolding was traditionally used in early education settings, it can be applied to higher education for complex subjects that are being taught for the first time, particularly in the form of peer-scaffolding.

Instructional scaffolding in technology-enhanced learning environments is used to address the possible effects of student learning development in collaboration with 'more able peers'. Jaeger's paper showed that Quality Mangers have the unique opportunity to assume a role that provides guidance without giving direct instruction. QMs are trained to be the "more able" peer within the classroom lab activity so that they can help bridge the instructor-student gap and take the classroom learning to the next level.

Peer-teaching opportunities arise when traditional methods of teaching are not fully supporting the learning style or needs of students. Peer teaching is a shift from traditional lecture to student-centered teaching. Goldschmid and Goldschmid [3] explored several models of peer teaching, none of which fits the model for this paper.

The practice of learning-through-teaching was discussed in detail by McIntyre [4] and Shih, et. al. [5]. This paper and its survey results of PAs confirms the claim made by McIntyre that, per "Learning- Through-Teaching allows students to gain valuable experience in: teamwork, organizing and delivering presentations, critical peer evaluation, and a better overall understanding the academic process." In other words, teaching a course requires deeper learning of the material than learning it yourself.

Zhan, Wei, et al [6] at Texas A&M University employed the student peer teacher model in a Circuit Analysis class offered to sophomore students in the Electronic Engineering Technology program with high success for imparting life-long learning skills. The Zhan peer teaching model utilized student peer teachers to teach course material from selected chapters of the textbook being used. This paper presents results of student peer teachers in an instructional role in their own laboratory section.

II. Implementing Laboratory Peer Teaching

The University of San Diego Shiley-Marcos School of Engineering laboratory courses are taught by either full-time tenure track faculty or by adjunct faculty instructors. Peer teaching was used in the laboratory portion that accompanies the first electrical engineering circuits course. The course is taken by all engineering sophomore-level students from the electrical engineering, industrial and systems engineering, and mechanical engineering programs. Assessments of the experience of the PAs and the learners were conducted.

In this paper, students enrolled in the laboratory course act as PA's on a rotating basis, taking responsibility and becoming intimate stakeholders for the educational and instructional outcomes of the laboratory course. Unlike QM's in the ATLAS model, the PA's were student enrolled in the course who took the role of peer instructors for specific laboratory experiments. A pair (except for one three member cohort) of Student Peer Assistants (PAs) were assigned to each laboratory experiment for the electric circuits course and met with the course faculty instructor prior to the experiment taking place for the rest of the class section.

The PAs were instructed by the faculty instructor on the week's upcoming laboratory experiment's theoretical foundation, relevant calculations, computer simulation techniques and results, and instrumentation. The PAs were then responsible to perform all of the tasks required for the particular laboratory experiment including designing, developing, and testing of the experimental hardware using basic passive electrical components and relevant laboratory instrumentation.

The laboratory exercises for the course are listed below. Those with asterisks by the title of the laboratory experiment were instructed by the PAs.

1. Resistor characteristics
2. Series and parallel resistive circuits
3. *MUTISIM* Tutorial *
4. Resistive circuits: Potentiometers - *MUTISIM* simulation, design and measurement *
5. Experimental realization of superposition *
6. Oscilloscope basics *
7. Thévenin equivalent circuits *
8. Introduction to operational amplifiers *
9. Introduction to *AC* measurements
10. Transients in series *RLC* circuits *
11. Introduction to simple *RLC* filters
12. Sinusoidal excitation of *RLC* circuits *

Because this was the first time implementing the laboratory peer teaching method, the initial two lab exercises that required significant introduction to electronic instrumentation were chosen to be taught by the laboratory faculty instructor. After observing PAs and student learning peers learn to effectively use new instrumentation and techniques, it appears that all experiments in the Fall 2013 laboratory section could have been taught by PAs.

The PAs' responsibilities included the following:

- Working the course instructor prior to the laboratory experiment period to develop the basic instructional and experimental methodology
- Organizing and teaching the theory, implementation, simulation, and instrumentation for the assigned laboratory experiment
- Preparing a classroom-type presentation for the assigned laboratory experiment
- Working with the instructor, who acts as the course facilitator, during the lab period
- Taking an active role in mentoring student groups working on the experiment

The faculty instructor's responsibilities included the following:

- Acting as an equal partner in the experiment
- Providing all of the experimental procedures
- Attending all presentations, and completing all of the required evaluations
- Grading all laboratory reports
- Developing and implementing a survey for all students in the course to assess the peer-teaching method employed
- Developing a summary report of the results of the surveys

The student PAs are evaluated based on their preparation and presentation during the sessions' introductory presentations and on their interaction with their peers during the experiment. Each member of the peer teaching team completes before and after surveys.

III. Assessment

In the fall semester of 2013, 15 students were enrolled in the sophomore level electric circuits course and its accompanying laboratory section. At the University of San Diego, the students taking the course in the fall semester are out of the standard curricular sequence where enrollment in electric circuits is primarily in the spring semester. More assessment will be conducted for the larger population of students in multiple sections of the electric circuits course in the spring 2014 semester. Preliminary student assessment of the effectiveness of peer teaching is summarized here.

The primary aim of this study was to assess student learning in the electric circuits laboratory using peer teaching. The assessment was in two parts:

- One for the peer instructors (before and after their assigned teaching laboratory time period) and
- the second for the entire class to assess their view of employing peer teachers.

Short questionnaires were designed to provide insight into the student level of knowledge and confidence in the circuit theory and experimental design for the assigned lab experiment for the peer teachers. At the beginning of each lab, student peer teachers were asked to score (on a scale from 1 to 5) their prior knowledge. To provide further insight into actual student knowledge level, students were asked to respond with a short answer to the knowledge questions. After the design exercise was completed, the questionnaires were again completed by the students and the post-exercise written responses were used to measure changes in knowledge level. In order to track individual student incremental changes, each survey was coded with a secret number, thereby preserving student anonymity. The use of student-assigned scores to assess gains in student knowledge and confidence has been successfully used by the investigator team in previous studies by Schubert, et. al. [7][8].

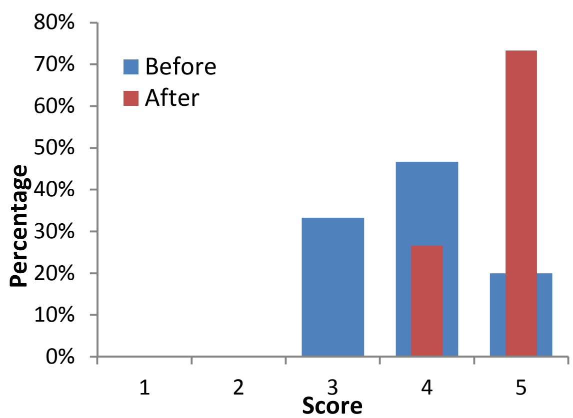
The following eight questions concerning knowledge concerning transistor capacitance modeling were asked before and after the lab exercise:

1. I can implement the circuits for the lab exercise.
2. I can properly use the required instrumentation required for the lab exercise.
3. I can use the electric principles utilized in the lab exercise.
4. I can properly explain to my peers the laboratory procedures.
5. I can properly explain to my peers the theory required in the lab exercise.
6. I can answer student peer questions regarding the lab.
7. I can de-bug circuits.
8. I understand the concepts explored in the laboratory exercise.

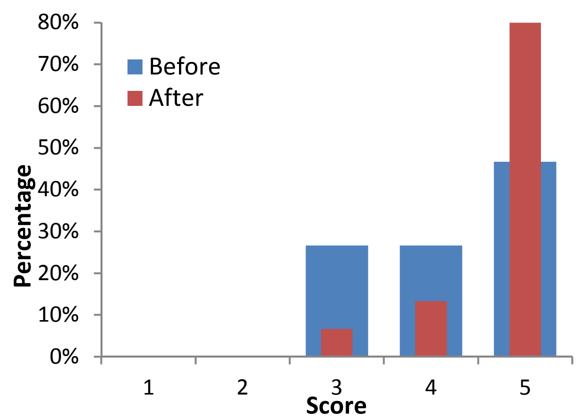
The knowledge score was based on the following scale:

1 = No Clue, I have no idea if I can apply the concept
2 = Low, I have heard of the concept, but have little confidence that I can apply it
3 = Moderate, I think I understand the concept, but am unsure about applying it.
4 = High, I am fairly sure I understand the concept and am fairly sure I can apply it.
5 = Superb, I am very confident that I understand the concept and can apply it to a new problem

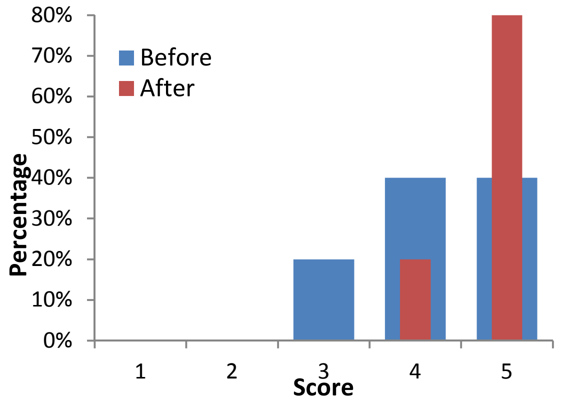
A larger sample of the distribution of students' answers on their knowledge before and after the exercise will be provided at the conference when a larger data sample is achieved in Spring 2014. The results of the Fall 2013 peer teaching confidence survey follows



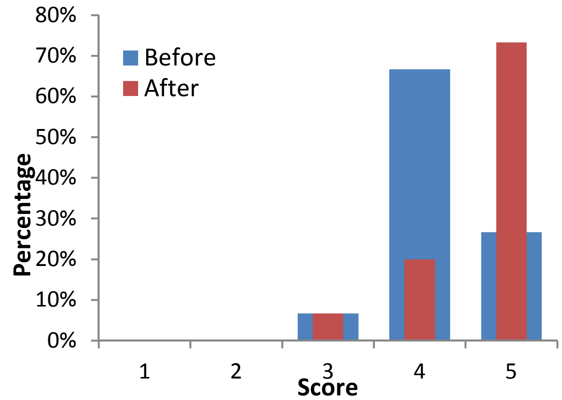
1. I can implement the circuits for the lab exercise.



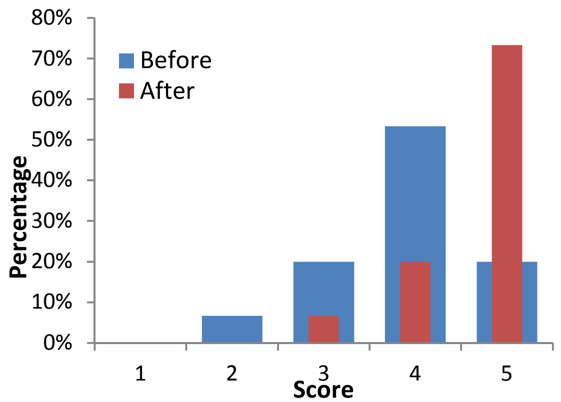
2. I can properly use the required instrumentation required for the lab exercise



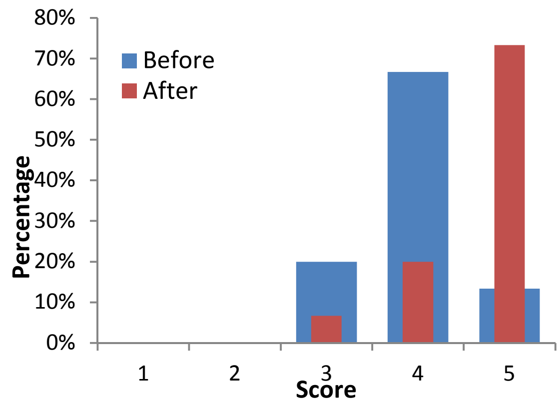
3. I can use the electric principles utilized in the lab exercise.



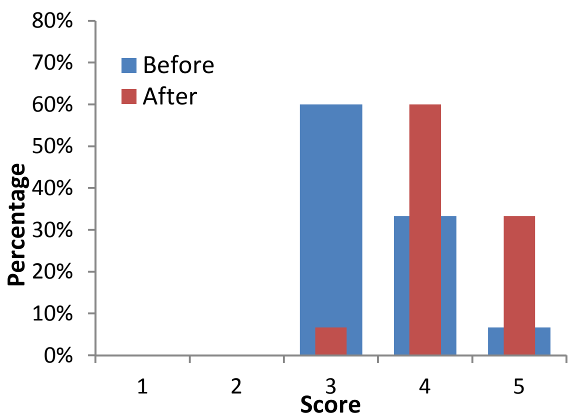
4. I can properly explain to my peers the laboratory procedures



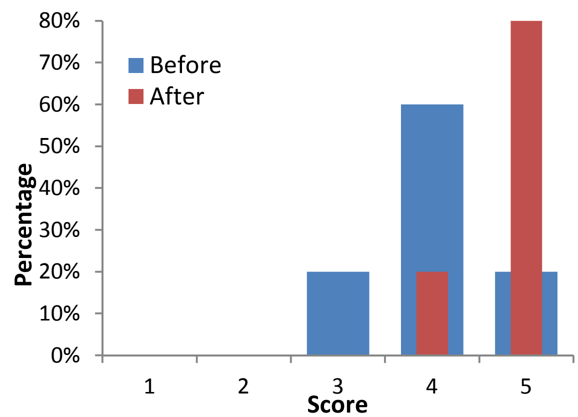
5. I can properly explain to my peers the theory required in the lab exercise.



6. I can answer student peer questions regarding the lab.



7. I can de-bug circuits.



8. I understand the concepts explored in the laboratory exercise.

Another portion of the questionnaire was designed to assess student confidence in as a peer teacher for the laboratory session to which they were assigned as the peer teacher. The following three questions were asked before and after the exercise were performed in order to assess student confidence:

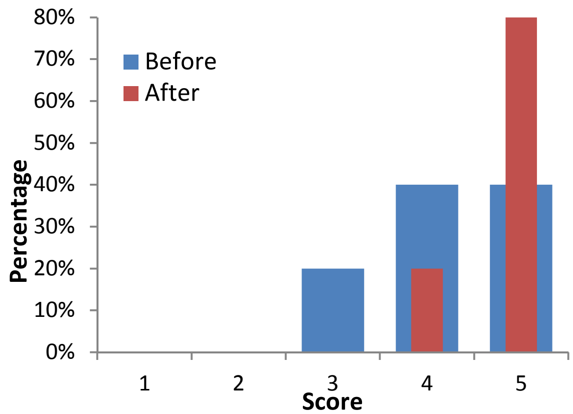
1. I can use all the instruments required for the lab to measure the required parameters.

2. I understand the principles that are to be demonstrated in the laboratory exercise.
3. I can make the appropriate calculations required for the laboratory exercise.

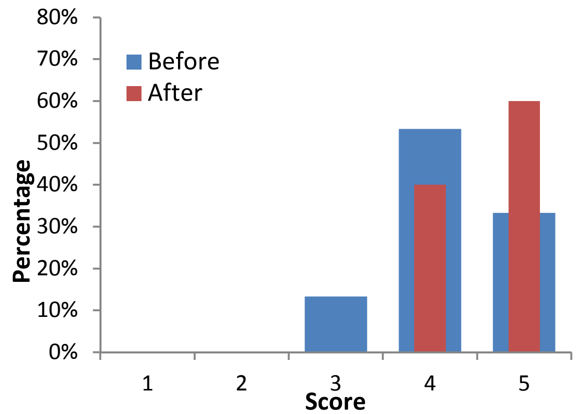
The confidence score was based on the following scale:

1 = No clue, this concept is new to me
2 = Low, I have only heard about the concept
3 = Moderate, I know about the concept, but have not applied it
4 = High, I know the concept and have tried it
5 = Superb, I know the concept and have successfully applied it

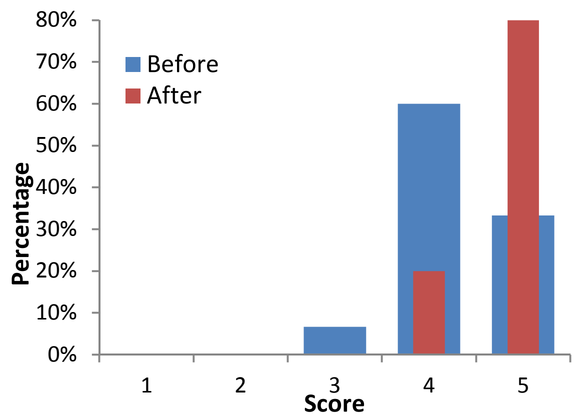
The distribution of students' answers on their confidence as peer teachers before and after the exercise for Fall 2013 are shown below. Results with a larger sample size from Spring 2014 will be presented at the conference.



1. I can use all the instruments required for the lab to measure the required parameters.



2. I can use all the instruments required for the lab to measure the required parameters.



3. I can make the appropriate calculations required for the laboratory exercise.

The final survey assessing general opinions of using peer teaching in an electrical circuits was conducted. The following ten questions were asked at the end of the semester:

1. This form of student-lead instruction enhanced my knowledge about the course material
2. My lab skills have improved due to this form of student-lead instruction

3. I learned more as a student presenter
4. I learned more from the other student presenters
5. This form of student-lead instruction enhanced my learning experience
6. I like this form of student-lead lab instruction better than traditional faculty-lead lab
7. I learned more in this lab course than in a typical lab course
8. I'd like all lab courses to be taught in this format
9. My teamwork skills have improved because of my experience as a team presenter
10. I have more confidence in my skills because of my experience as a team presenter

The opinion score was based on the following scale:
1 = Strongly Disagree
2 = Disagree
3 = Neutral – Neither Disagree or Agree.
4 = Agree.
5 = Strongly Agree

The results of the opinion score (Table 1) showed that in general, students were neutral or somewhat agreed with peer teaching in the electrical engineering laboratory course. Three notable exceptions were the following questions:
3. I learned more as a student presenter
9. My teamwork skills have improved because of my experience as a team presenter
10. I have more confidence in my skills because of my experience as a team presenter

For these three questions, 63% of the students selected the highest score, Strongly Agree.

Table 1. Final Survey Results

Opinion	Average Score	Standard Deviation
1. This form of student-lead instruction enhanced my knowledge about the course material	3.43	1.31
2. My lab skills have improved due to this form of student-lead instruction	3.29	0.92
3. I learned more as a student presenter	4.14	1.39
4. I learned more from the other student presenters	3.43	0.74
5. This form of student-lead instruction enhanced my learning experience	3.43	0.76
6. I like this form of student-lead lab instruction better than traditional faculty-lead lab	3.29	0.74
7. I learned more in this lab course than in a typical lab course	2.86	0.64
8. I'd like all lab courses to be taught in this format	3.29	0.71
9. My teamwork skills have improved because of my experience as a team presenter	4.14	1.16
10. I have more confidence in my skills because of my experience as a team presenter	4.14	1.46

V. Summary

The efficacy of using student peer teachers for an electrical engineering laboratory course was studied.

Summary scores for student peer teachers' confidence before a laboratory exercise was an average of 3.97 with a standard deviation of 0.73. The summary score after the exercise was an average of 4.67 with a standard deviation of 0.56 resulting in overall increase in confidence of student peer teachers.

Summary scores for student peer teachers' knowledge before a laboratory exercise was an average of 4.22 with a standard deviation of 0.67. The summary score after the exercise was an average of 4.73 with a standard deviation of 0.45 resulting in overall modest increase in knowledge of student peer teachers.

The overall opinion of students to peer teaching was an average of 3.59 with a standard deviation of 1.06 indicating that students were unsure of the value of peer teaching as applied to them as a learner. However it appears that students particularly valued their experiences as peer teachers as an aid in learning, teamwork skills, and building confidence.

VI. Continuing Work

In the spring 2014 semester, two of three sections of electric circuits laboratory will use student peer teachers. The same surveys used in the fall semester of 2013 will be used in the spring of 2014. One of the sections in the spring 2014 semester will be faculty instructor led and will not use student peer teachers. The identical survey instrument for student knowledge and confidence will be completed by all individuals in that section. The lab experiments for all three sections will be identical on a weekly basis. Comparison of the faculty instructor led "control" group with the peer teacher led sections will be presented at the conference. The comparison of the control group and the peer assistants' sections will consist of an end of Spring 2014 semester individual student lab practicum.

Additional data will also be gathered in a section of the Mechanical Engineering Fluid Mechanics laboratory in Spring 2014. The results of the surveys in the Fluid Mechanics laboratory will be reported at the Annual Conference of the ASEE in June 2014.

Acknowledgement

USD Institutional Review Board approval was obtained for the Fall 2013 and Spring 2014 semesters.

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