Research and Practice Group Methodology: A Case Study in Student Success

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Abstract

Experiential learning is a key component in engineering education. In civil engineering, this component is typically delivered through multiple projects. These projects may include term projects for individual courses, senior design projects, theses, or independent studies. The focus of these experiences may gradually shift from practice-oriented projects in undergraduate studies to research-oriented projects in graduate studies. Thus, learning objectives should always address both areas with a strong emphasis on common fields, such as applied research. Experiential learning has the capacity to include various program-level outcomes, such as technical knowledge, communication and teamwork. Development of a research and practice group facilitates these outcomes by creating an environment to share the learning experience. Such a group should replicate the working environment of civil engineers by incorporating multidisciplinary projects and diverse individuals, including cross-generational members. As a case study, this work examines a Research and Practice Group at California State University Fresno. This group consists of junior and senior undergraduates, graduate students, and former members who are participating as alumni. The major focus of research within the group is resilient and sustainable structural mechanics and design. This paper outlines the methodology that has been employed to ensure academic and professional success for members of the group. This methodology incorporates a recruitment process, meetings, consultation, mentorship, networking, and support. The level of student success achieved by the group is presented in terms of the achievements of the group's members. This includes a discussion of completed projects, research funding, and group presentations. To further demonstrate the efficacy of the methodology, students in the research group are compared to the general body of engineering students at CSU Fresno though the results of a survey. This survey is analyzed using traditional methods, as well as Latent Semantic Analysis. Our results indicate that group members are better at embodying and communicating outcomes than the rest of the student body, and that the research and practice group provides an experience that allows students to internalize and take responsibility for their own goals.

Introduction

Experiential learning is a key component in engineering education. The ASCE Body of Knowledge (BOK) considers professional experience to be a required supplement to bachelor and master degrees[1]. The requisite pre-licensure experience is expected to directly fulfill the highest level of achievement for most technical and all professional outcomes (see Table 1). Further, hands-on experience facilitates the achievement of foundational outcomes (mathematics and science), as well other areas of technical outcomes (for example, material science and

mechanics). Thus, experiential learning does not necessarily have to begin after graduation. Rather, it should be incorporated in engineering programs throughout both undergraduate and graduate curricula.

Table 1. The BOK outcomes with respect to experience[1]

Technical	Professional
Design Sustainability Contemporary issues Risk and uncertainty Project management Technical specialization	Communication Public Policy Business and public administration, Globalization Leadership Teamwork Attitudes Lifelong learning Professional and ethical responsibility

In civil engineering, experiential learning is typically delivered through multiple projects that form the culminating experience for completion of a course or degree. These projects may include term projects for individual courses, senior design projects, theses, or independent studies. Many undergraduate design courses are often accompanied with term projects. For example, a course in design of steel structures may require a culminating design project.. The purpose of such projects is to enable students to apply engineering knowledge and skills to solve relevant engineering problems. In this regard, students are expected to follow specific standards and procedures. This expectation shifts to another level of achievement in a senior design or capstone project, where problems are more complex and require more rigorous decision making as well as communication within a team. Further, the nature of a senior design projects typically introduces aspects of design that are new to students, such as risk, uncertainty, and project management. A capstone project is generally the most complex experiential assignment in a bachelor degree program.

Comparison of bachelor and master degree curricula shows that the focus of these experiences may gradually shift from practice-oriented projects in undergraduate studies to research-oriented projects in graduate studies. A bachelor thesis, an option provided in many engineering schools, serves as a smooth transition from practice-based projects to research-based projects. A graduate research project fulfills highest level of curriculum achievement for multiple technical outcomes, including experiments, problem recognition and solving, and technical specialization. Thus, the learning objectives should always address both areas of research and practice, with strong emphasis on common fields, such as applied research.

Experiential learning has the capacity to include various program-level outcomes, such as technical knowledge, communication and teamwork. Table 2 lists ABET (2010) and ASCE (2008) learning outcomes that are fulfilled through research projects. The levels of achievement cover a range of activities from which students may obtain knowledge; these are comprehension, application, analysis, synthesis, and finally evaluation.

Table 2. Mapping course learning outcomes to engineering outcomes[1,3]

Engineering Outcomes (ABET, 2010)	Civil Engineering Outcomes (ASCE, 2008)	Experiential Learning
(a) Mathematics, science, engineering	1. Mathematics 2. Natural sciences 3. Materials science 6. Mechanics 14. Breadth in civil engineering areas 15. technical specialization	Application
	3. Humanities 4. Social sciences	Application
(b) Experiments	7. Experiments	Synthesis
(c) Design	9. Design	Evaluation
	10. Sustainability 12. Risk / uncertainty	Analysis
(d) Multidisciplinary teams	21. Teamwork 20. Leadership 22. Attitudes	Analysis
(e) Engineering problems	8. Problem recognition and solving	Analysis
(f) Professional and ethical responsibility	24. Professional and ethical responsibility	Evaluation
(g) Communication	16. Communication	Synthesis
(h) Impact of engineering	11. Contemporary issues and historical perspectives 19. Globalization	Analysis
(i) Lifelong learning	23. Lifelong learning	Synthesis
(j) Contemporary issues	11. Contemporary issues and historical perspectives 19. Globalization	Analysis
(k) Engineering tools	8. Problem recognition and solving	Analysis
	13. Project management	Analysis
	17. Public policy 18. Business and public administration	Application

Further, the characteristics of independent studies, research projects and thesis fit the highest level of student development in situational teaching model as shown in Figure 1[4]. In this model, students begin their journey in an engineering program by obtaining direct guidance in early

introductory courses (for example, a course introducing the engineering discipline). Later, they will receive essential knowledge in basic engineering courses, such a structural mechanics or dynamics. During senior year, students gain confidence to apply the knowledge of engineering in design courses (for a example, a course in design of steel structures). Finally, a senior project allows students to be responsible-in-charge[2].

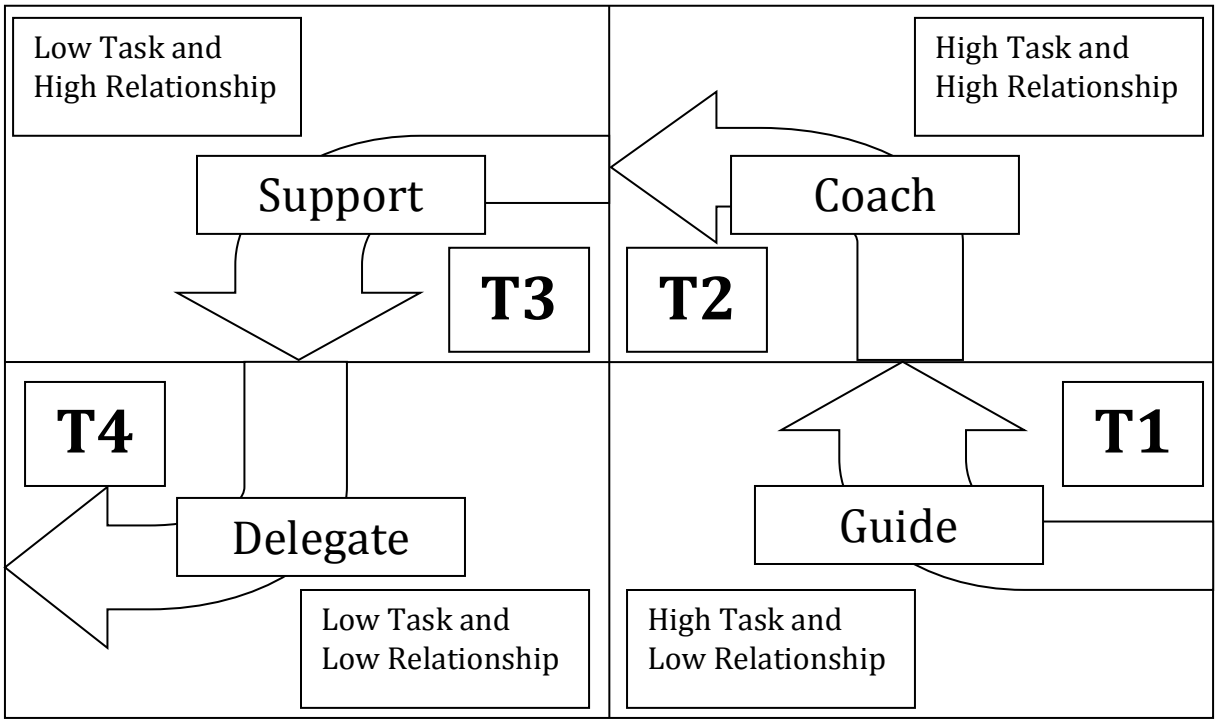

Figure 1. Situational Leadership, after Hersey et al. (1982)

Objectives and Purpose

Research groups have long been a key component of the university environment. Such groups are typically composed of supervising faculty members and graduate students at the masters or doctoral levels. The primary purpose of these groups is to support research and, to a lesser degree, teaching activities. However, we characterize the group studied in this work as a Research *and* Practice Group. This distinction is made to emphasize the fact that this group also supports activities that prepare students to practice engineering. In this way, the group also ensures student success by building upon the tenets of the Relational Leadership Model[5]: purpose, inclusion, empowerment, ethics, and process.

Further, the development of a research and practice group facilitates learning outcomes of engineering education by creating an environment in which the learning experience can be shared. Abbas, Alhammadi, and Romagnoli (2009) considered the notion of facilitating, rather than teaching, in development of a senior elective course within an engineering curriculum. The project-based course yielded positive learning outcomes, including teamwork and communication. Further, the course promoted ownership of learning and research, individual accountability, and personal responsibility, as key attributes of the transition from student to

engineer. Lack of these attributes in engineering graduates prevents them from taking charge of large-scale projects[9]. Industry often requires their employee to attend project-based internship programs to fill this gap. In this regard, a research and practice group can effectively replicate the working environment of civil engineers by incorporating multidisciplinary projects and diverse individuals, including cross-generational members.

Duarte et al. (2012) took a more bottom-up approach to enhance engineering education. In this approach, research groups were formed as student-led initiatives. Ph.D. students provided leadership, and recruited undergraduate students. The report shows that the sense of belonging and ownership in these groups facilitated acquiring personal and professional competencies. Further, the student-led characteristic of these extracurricular groups helped the faculty to manage the time-consuming training of new students and keep them motivated throughout the project. These results introduce the role of advisor as a parameter in effectiveness of the research groups. Crede and Borrego (2012) offered a study on how research groups foster such qualities for students. This study reported on several elements including communication, resources, and role of advisor, in relation to the group size. Results indicated that mid-size groups (5 to 20 students) offer a balance in communication and resources. Students in these groups tend to ask for support from the advisor as well as other students. Further, these students stated that the advisor did a better job in communicating clear expectations. The advisor role in such groups generally includes enculturation and gatekeeping. Further, larger groups (11-20) provided better funding opportunities for students. However, the study also revealed that students feel more comfortable speaking in small groups (less than 5).

This work examines a group at California State University Fresno as a case study. This group consists of junior and senior undergraduate and graduate students as well as former members who are participating as alumni. The major focus of research within the group is resilient and sustainable structural mechanics and design. The group meets once every three to four weeks, either in-person or via web, to share their current work through presentations. Further, the faculty adviser provides guidance on essential communication skills, such proposal development and professional presentation. Slide and video presentations are archived and shared for future reference. The meeting is well attended by both members and guests, including non-member students, faculties, and the dean. These meetings enable presenting students to obtain feedback and comments from their fellow classmates and alumni in a friendly environment. The unique composition of the group also allows members to improve their ability to reach audiences at various academic levels, from undergraduate freshmen to senior graduate students and even practicing engineers. Further, younger members have the great opportunity to learn about current research projects and presentation skills. Moreover, students continue to develop their research skills, including development of ideas, proposals, literature studies, methodologies, and reports, during individual advising sessions. Students learn how to present their work using slides, posters, lectures, and documents. Furthermore, students are fully supported to apply for graduate studies, internship, and funding opportunities.

Methodology

This section outlines the methodology that has been employed to ensure academic and professional success for members of the research group. The proposed methodology focuses

simultaneously on concerns for people and results. These are identified as the two dimensions of style approach to team management in Hersey et al. (1984). The primary tenets of the methodology with concern for people are:

1. Recruiting students from all academic levels to create cross-generational relationships,
2. Regular in-person and online meetings to promote effective communications,
3. One-on-one consultation with faculty as an essential advising approach,
4. Mentorship and networking opportunities in small, student-led groups to foster teamwork and leadership,
5. Group support for academic and professional goals to develop recognition for life-long learning.

These tenets are discussed further in the following sections of this paper. With the exception of recruitment, the tenets are not discussed directly. Rather, the remaining tenets are discussed holistically in relation to the general procedure of the group, the diversity of the student body, the projects undertaken by the group, and deliverables provided by members. It should be noted that diversity is perceived as an overlay on the entire procedure, rather than a stand-alone component. In addition, note that the concern for results[4] is exhibited in the methodology for assessing outcomes of the research group, which is discussed as part of the sections on projects and deliverables.

Recruitment

To join the group, students take part in an interview with the supervising faculty. The purpose of the interview is to evaluate the student's academic preparation, motivation, dedication and commitment toward research, teamwork, and potential for growth. Prospective interviewees are not chosen exclusively by the supervising faculty. Current group members are encouraged to recommend interviewees, and this is recognized as an essential component in ensuring the sustainability of the group. This process assures that junior members can develop their skills gradually to fill the position of senior members in the interest of continuity. Currently, active members of the group consist of five undergraduate students, six graduate students, and four alumni members who are actively presenting and attending meetings in addition to working on their own projects.

Procedure

An ideal research program for students begins at junior level. At this stage, students explore possibilities in research under supervision of the faculty advisor. They learn key components of research and proposal development through general studies, attending presentations, and helping senior students. Junior students meet the faculty advisor once a month to discuss their research interests as well as academic and career goals. As students make progress toward senior status, they begin writing proposals on selected topics. Undergraduate students also participate in major research projects by assisting graduate students. Their training at this stage includes laboratory safety, literature studies, data mining, documentation, and presentation skills. At senior level, students may choose to enroll in an independent study, implement their research skills in senior design project, or define an undergraduate thesis. At this stage, they meet advisor at least twice a

month to learn about experimental and analytical studies. A typical undergraduate research should develop and implement either an experimental or an analytical plan using available resources in college.

At graduate level, students incorporate all previous components at a higher academic level. A typical graduate research includes both analytical and experimental studies in addition to literature studies, data mining, etc. Fresh graduate students coming from other schools may need additional training on research methods and components, if they have not learned them during their undergraduate programs. Further, graduate students are expected to mentor their undergraduate assistants in the laboratory. Therefore, developing supervising and mentorship skills are another part of their training. To accomplish such extensive training, graduate students meet the faculty advisor at least once a week. To prepare graduate students for PhD programs, they also participate as teaching assistant and grader, as well as developing proposals for external funding.

Alumni members of the group maintain their contribution by presenting their work in other institutes and organizations as well as sharing their experience and advice with new students. Such contributions also provide an opportunity for networking and development of partnerships between students as well as institutes.

Diversity

Current members represent significant participation by underrepresented groups, including Hispanic and female students. Figure 2 and Figure 3 show trends of students advised by supervising faculty in the past four years. The research and practice group was initiated in fall 2011. Thus, these figures clearly indicate the impact of the research and practice group on number of Hispanic and female students. The average percentages of Hispanic and female students over the past three years are 67% and 44%, respectively. These values are substantially higher than university, college, and department statistics, as shown in Table 3[14]. Such participation is outstanding and essential for the civil engineering program in a Hispanic Serving University, which is also a non-Ph.D.-granting institution. The research group has also successfully collaborated with other groups serving underrepresented students and communities, including Louis Stokes Alliances for minority Participation (LSAMP), Engineers Without Borders (EWB), Society for Advancement of Chicanos and Native Americans in Science (SACNAS), etc.

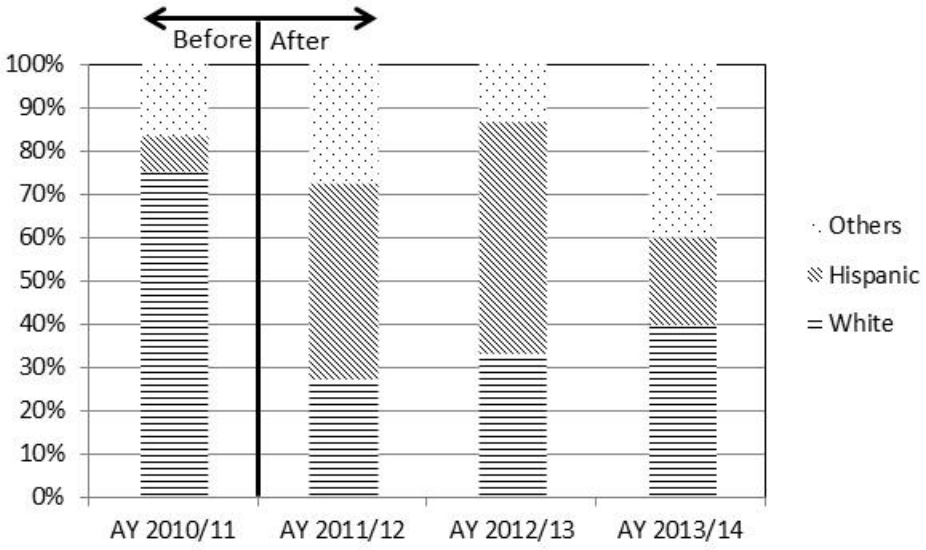

Figure 2. Group diversity with respect to ethnicity.

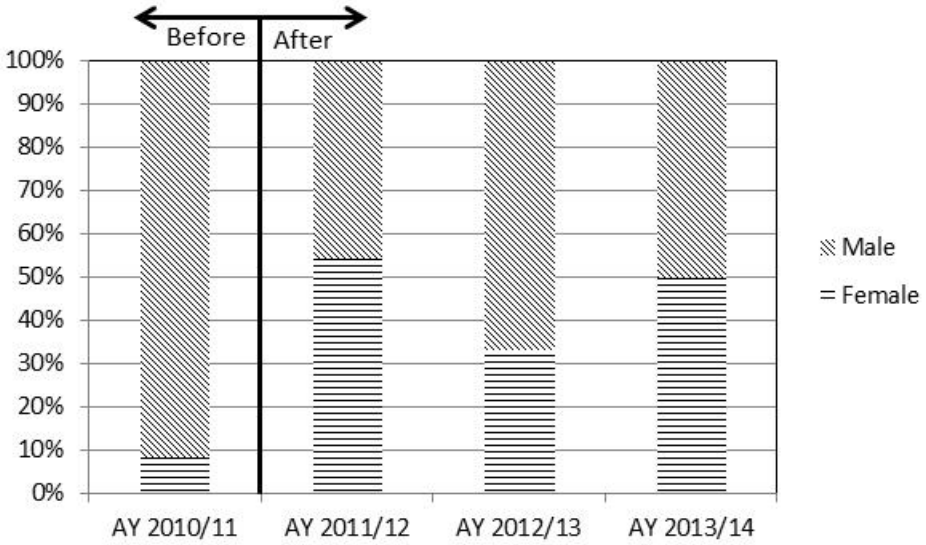

Figure 3. Group diversity with respect to gender.

Table 3. Demographic Data.

	Group Members	Department	College	University
Female students	44%	19%	13%	58%
Hispanic students	67%	39%	37%	41%

Projects

The focus of the group is resilient and sustainable structures, structural mechanics, and design. Research projects are developed based on student interests and their academic preparations. These projects typically include undergraduate and graduate thesis, projects and independent studies, as well as self-sustained projects. Senior undergraduate students may also present their senior design project, if the project includes innovative components that require research. Projects are customized based on the level of academic preparation of the individual student. Projects are generally planned for one or two semesters with possibility of extending the project in multiple years. Limiting each phase to one or two semesters gives students an opportunity to present their work, obtain feedback, and gain sense of accomplishment at least once a year. This aspect of the program was designed to motivate students to continue working on more long-term research programs.

Deliverables

Common deliverables for research projects include multiple written and oral presentations. Written reports include project proposals, progress reports, final project reports, and articles or technical papers appropriate for engineering magazines and journals. Poster, slide, and conference presentations are also part of project deliverables. Participation in university showcase events provides an opportunity for students to share their work with the university community. The faculty advisor also presents the group profile in an annual brochure. The current brochure includes complete list of participants, projects, presentations, and publications. If supported by the college, the faculty advisor may expand this brochure to an online digital publication, including articles and presentations,.

Results

This section assesses the efficacy of the methodology using a variety of methods. Results are presented in three sub-sections. First, the level of student success achieved by the group is presented qualitatively in terms of the achievements of the group's members. This includes a brief discussion of completed projects, research funding, and group presentations.. Second, the results of a survey are presented. The survey was provided to current members of the group, as well as general members of the student body. Third, a novel assessment metric is implemented. This assessment metric uses Latent Semantic Analysis to compare passages written by students (describing their skills and professional aspirations) to a set of learning outcomes. These outcomes are adapted from those of the American Society of Civil Engineers (ASCE) and Accreditation Board for Engineering and Technology (ABET).

Qualitative Student Success

The research group was started in 2011. Since its inception, members have received support for a variety of activities, including design projects, proposal-writing, communication of results, and team collaboration. Measurable outcomes of this support include:

1. Approximately 25 presentations given by students during group meetings

2. 4 journal papers in review
3. $44,300 in research funding secured by group members
4. More than 15 senior projects mentored through the group

These qualitative indicators demonstrate that the group provides students with a number of opportunities to encourage their success.

Survey Results

Seven current group members and 26 non-member students participated in the survey. All were civil engineering students. Characteristics regarding the group and non-group members are summarized in Table 4.

Table 4. Composition of Respondent Pool.

	Group Members	Non-Group Members
Total number	7	26
Junior and Below	14%	42%
Senior	29%	58%
Graduate	57%	0%
EIT Passed	71%	27%

Questions provided only to non-group members were intended to query their interest in participating in a research group. This was accomplished by querying their interest in a group that would support and offer feedback on a variety of activity. Several questions also asked if such support or feedback was being supplied by other groups. A positive response to a question was one that indicated interest or fulfillment, while a negative response was the opposite. A summary of these results is provided in Table 5.

Table 5. Non-Group Member Survey Questions and Results

No.	Question	Response Type	Response Classes	Response Percentage
1	If given the opportunity, would you participate in a group that would offer support and feedback for research activities?	Free Response	Positive	88%
			Negative	12%
2	Do you already participate in a group that offers support and feedback for research activities?	Free Response	Positive	12%
			Negative	88%
3	If given the opportunity, would you participate in a group that would offer support and feedback for your senior project?	Free Response	Positive	100%
			Negative	0%
4	Do you already participate in a group that offers support and feedback for your senior project?	Free Response	Positive	4%
			Negative	96%
5	If given the opportunity, would you participate in a group that would offer support and feedback for academic presentations?	Free Response	Positive	92%
			Negative	8%
6	Do you already participate in a group that offers support and feedback for academic presentations?	Free Response	Positive	0%
			Negative	100%

The results from this set of surveys indicate that there is a large desire for feedback and support regarding senior projects, academic presentations, and research activities. At the same time, the survey results indicate that these needs are largely not being fulfilled by other organizations. Therefore, the expansion of undergraduate research may be beneficial for ensuring student success of the student body.

Questions provided only to group members were intended to examine their experience as part of the group. Table 6 provides a list of questions that were only provided to members. Here, a positive response indicated agreement.

Table 6. Group Member Survey Questions

No.	Question	Response Type	Response Classes	Response Percentage
1	What was your motivation for becoming part of the group?	Multiple Choice (all that apply)	Academic Career/Professional Personal goals Other	71% 100% 29% 14%
2	What is your motivation for continued involvement in the group?	Multiple Choice (all that apply)	Academic Career/Professional Personal goals Other	86% 86% 71% 14%
3	Do you feel that the group gives you support and feedback for research activities? Why or why not?	Free Response	Positive Negative	86% 14%
4	Do you feel that the group gives you support and feedback for your senior project? Why or why not?	Free Response	Positive Negative	86% 14%
5	Do you feel that the group gives you support and feedback for your academic presentations? Why or why not?	Free Response	Positive Negative	71% 29%

In responding to Question 1, most participants selected either academic or career/professional goals, and only 29% selected personal goals as their motivation for becoming part of the group. However, in responding to Question 2, a much higher proportion of students selected personal goals as their motivation for continued involvement in the group. The large increase in the number of respondents who selected personal goals (an increase of 43%) indicates that group members internalized responsibility for their own success. In addition, nearly all members stated that they received support for a range of activities as part of the group (Questions 3, 4, and 5). This indicates that the non-group members could actually have those needs fulfilled as part of the group.

Latent Semantic Analysis

Latent Semantic Analysis has been used extensively in the design theory and methodology literature for comparing written description of design solutions[10,11]. At its most basic, Latent Semantic Analysis (LSA) is a computational tool that compares documents based on the relative frequency of occurrence of words. More specifically, a word-by-document matrix is first created. Columns represent documents, and rows represent unique words occurring in the total corpus of text. A weighting is then applied to the matrix to condition the data. In this work, log-entropy weighting was used because it has been shown to perform well across many data sets[12].

Finally, documents are compared by calculating the cosine similarity between columns. The cosine similarity metric ranges between 1 (indicating that the two documents are identical) to -1 (indicating that the two documents are *extremely* dissimilar).

A portion of the survey collected a written response to the prompt: "*Describe yourself as an engineering student. Discuss relevant strengths, personal attributes, and experience".* Participants were asked to refrain from substantially editing or revising their response. The participants' written responses were compared to a list of educational outcomes using LSA. Rather than state "cosine similarity to education outcomes" throughout the following discussion, we will simply use "cosine similarity" as the preferred terminology.

The average response length was 84 words. Two-dimensional representations of the LSA analysis were produced by performing non-dimensional scaling on the document-similarity matrix using the MATLAB Statistics Toolbox[13]. The axis labels, x_1 and x_2, indicate the components assigned by this analysis. Figure 4 depicts the relationship between members and non-members with respect to the list of outcomes.

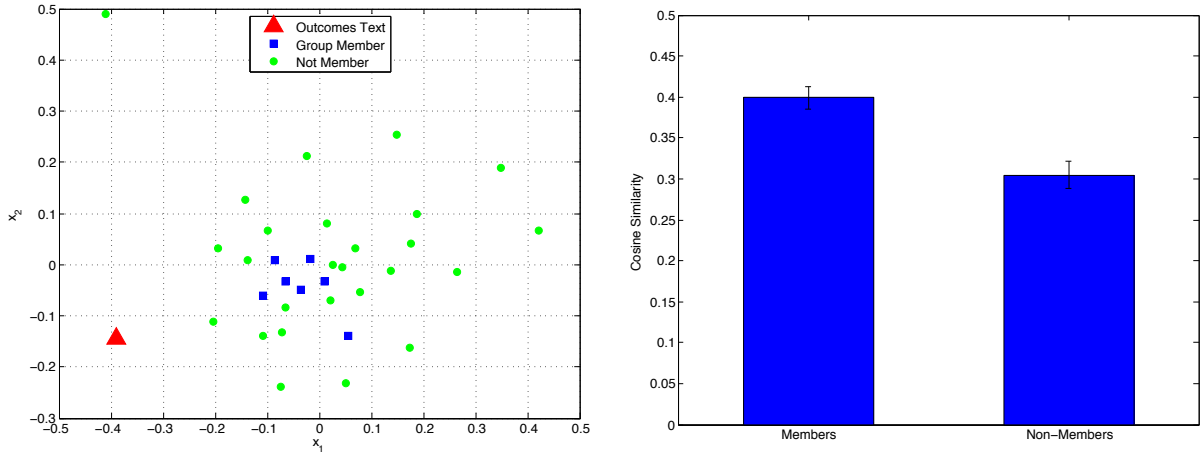

Figure 4. Relationship between written responses for group and non-group members. (error bars show ±1 S.E.)

In the two-dimensional representation, non-group members show a large amount of variance, as might be expected, while the group members are tightly grouped. The group members show a significantly higher level of cosine similarity than do non-group members (ρ =0.006, F=8.760). In other words, the responses written by group members are more similar in content to the list of outcomes than those of non-group members. This could indicate that group members more effectively embody and communicate ASCE and ASEE outcomes. Figure 5 compares the cosine similarity of different education levels.

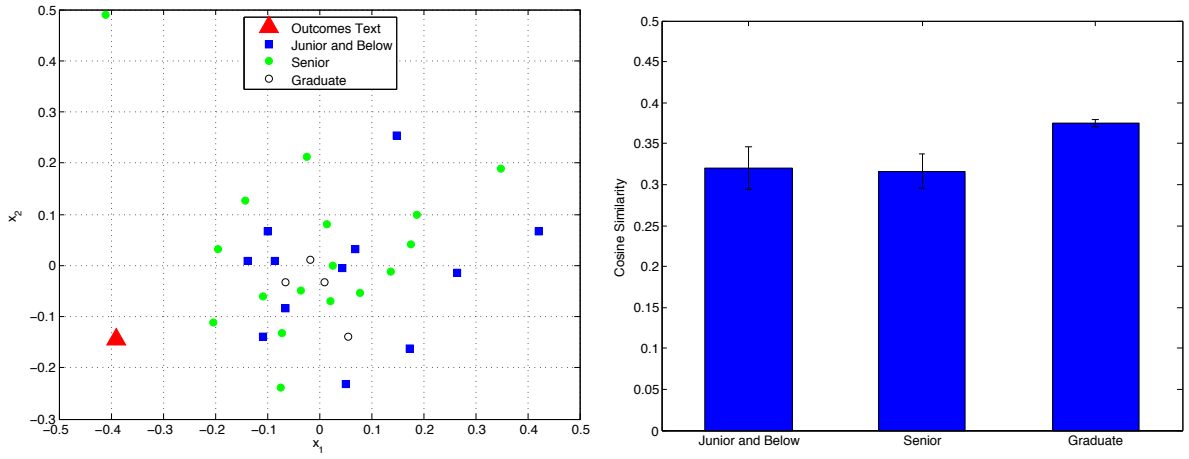

Figure 5. Relationship between written responses for different educational levels. (error bars show ±1 S.E.)

There was not a statistically significant difference between any two of these three groups (juniors and below, seniors, and graduates). Therefore, it is more likely that the higher cosine similarity of group members was caused by association with the group.

A possible limitation of the current analytical results is that no attempt was made to control for individual aptitude. Students that excel because of personal aptitude could be more likely to join the research and practice group and would also, seemingly. Additionally, the written statements provided by these students could have exhibited higher similarity to the outcomes text, making personal aptitude a driver for the difference between group and non-group members. In future work, this potential limitation could be addressed by collecting multiple written statements from students on an annual basis. This would allow the impact of participation in the research and practice group to be examined in a temporal sense.

Conclusion

In this paper, we introduce a methodology for the effective delivery of a Research and Practice Group to ensure student success. This methodology is grounded in encouraging an integrated experiential learning environment. The methodology also draws upon both situational leadership and relational leadership models. The five primary tenets of the methodology are discussed, and we justify their inclusion by demonstrating support for similar strategies in the literature. In less than 3 years, this group has provided many opportunities for student to ensure their own success. This includes research funding generated by the group, group presentations given by students, and mentoring for senior projects. In addition, a survey was administered to both group and non-group members. The results of the survey indicate that the general student body desires participation in such a research group; that the group does provided support and feedback for members; and that the group provides a transformative process that allows members to develop personal goals. Further, we compared written samples of students' self-descriptions to a list of expected education outcomes (developed from ASEE and ASCE standards). Group members showed significantly higher similarity to the list of outcomes than non-group members,

indicating their enhanced ability to internalize and communicate those outcomes. This combination of both quantitative and qualitative evidence supports the efficacy of the group methodology proposed in this work.

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