AC 2012-4874: THE TEACHER EFFECT: EXPLAINING RETENTION GAINS IN FIRST-YEAR ENGINEERING PROJECTS COURSES

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The Teacher Effect: Explaining Retention Gains in First-Year Engineering Projects Courses

First-Year Engineering Projects Courses (FYEP) courses have been found to produce significant retention gains. [1] Investigation is on-going into the reasons driving theses retention gains. Possible reasons include the development of self-efficacy, involvement in learning communities, the bolstering of professional identity, project-based learning and the unique set of skills possessed by the teacher of the FYEP course. The present study investigates the last of these reasons, the impact of the FYEP teacher on the course experiences that lead to retention.

At a flagship western state university, the retention in engineering of seventeen cohorts of students is found to be significantly greater for those who have taken the FYEP course (shown in Figure 1).

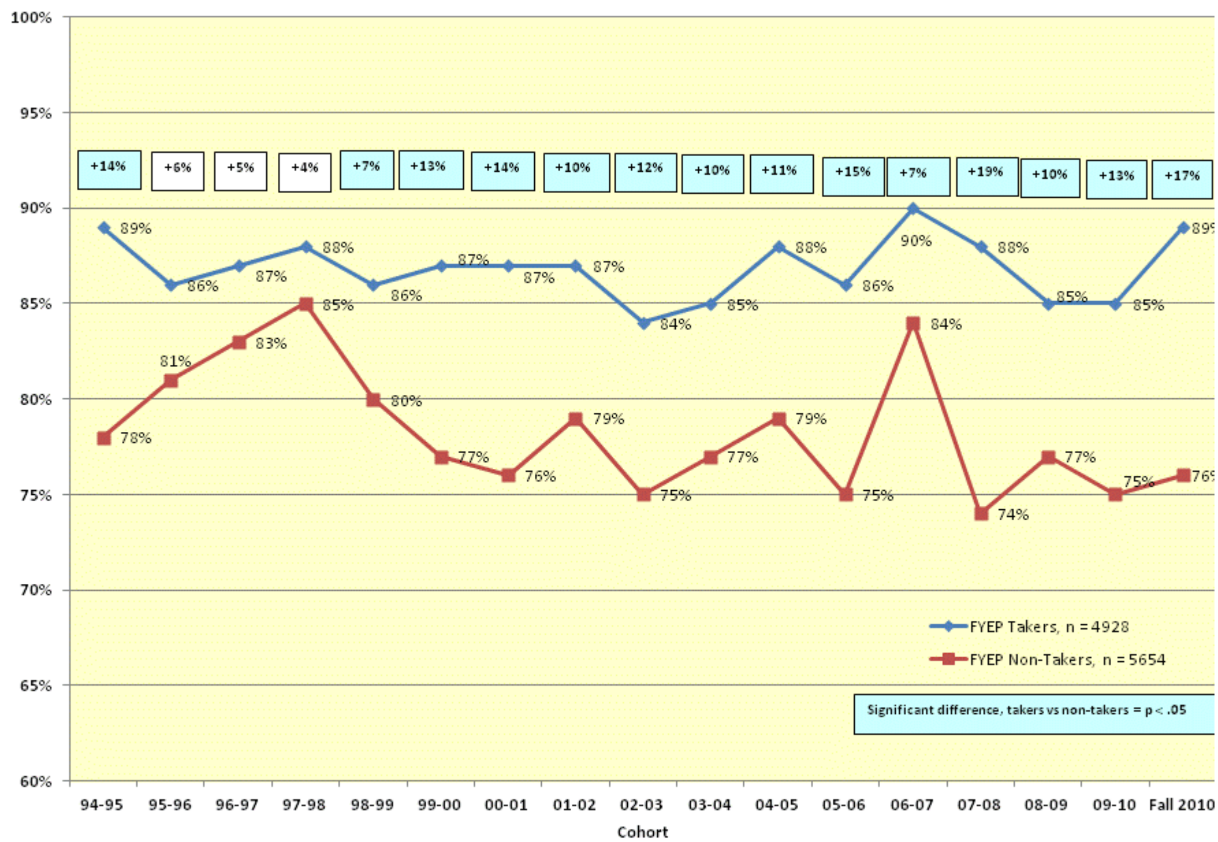

Figure 1. Third semester retention rates of first-year engineering projects takers vs. non-takers fall 1994 - fall 2010 (n =10,582).

Longitudinal tracking of student cohorts since fall 1994 shows a sustained increase in retention into the third semester, as well as into the seventh semester which is a strong indicator of retention through to graduation. For example, for the cohort that enrolled in fall 2007, a 10% increase in retention demonstrated by the third semester increases to 18% by the seventh semester. [1] This sustained difference over the years forms the starting point for the current study. The study research question is: *Does the FYEP instructor implement a set of skills and attributes that bolster their students' persistence?*

Background of the FYEP Course

Persistence in engineering can be attributed to building motivation and aligning students' interests with their environment, establishing achievement and self-concept about one's abilities, and by their overall growth in self-efficacy related to engineering. [2, 3] Developing disciplinary knowledge contributes to forming engineering identity. [4] In recent years, active learning strategies have been related to increased persistence. [5] While the use of clicker questions, paired discussions and other critical thinking exercises have been increasingly incorporated into lecture settings, the laboratory environment has long been recognized as an effective way for students to develop disciplinary knowledge through active learning; many engineers learned how theoretical ideas are translated into real-world practices through hands-on work with the equipment, techniques and testing used in their disciplines. Incorporating a design-build-test model can be viewed as an extension of these laboratory experiences. Through projects courses, students learn to channel their creative ideas by building projects that actually function. These projects courses combine many different active learning strategies including open-ended, problem-based learning. [6]

The FYEP course at the University of Colorado Boulder makes use of a team-based, design-build approach culminating in a tangible project by the end of the semester. About half the first year cohort (~700) enrolls in the course; of these, 66% fulfill a major requirement and the rest volunteer for the course. Previous research has not found differences in retention between volunteers and required takers.[1] FYEP survey and focus group assessments indicate growth in technical areas as well as satisfaction with the course from the variety of classroom experiences that enhance students' engineering abilities while helping to develop their identity as an engineer. Hands-on and teamwork experiences also contribute to students' knowledge of engineering as a career.

The FYEP course follows a curriculum plan that is uniquely different from the typical first-year course. Students encounter no exams, self- and peer-reflections (i.e., writing!) are assigned, and collaborating with fellow classmates is expected. A problem-based learning (PBL), active approach is used to guide the learning experiences of these students. After the formation of semester-long teams, students take on challenging, open-ended projects in diverse topics such as assistive technology, Rube Goldberg, sustainable technology, science concept demonstrations, recreating existing devices and robotics challenges. Along the way, students must develop sufficient proficiency in technical drawing, testing, machining, electronics, and/or programming—areas in which most students have little to no experience— to be able to develop and produce a working device. While trial-and-error could be used, the students are guided by the steps in the engineering design process [7] as well as the goals of their small, team-based learning community. Professionally valued skills including written and oral communications, leadership, personal responsibility, integrity and respect also are cultivated in the team setting. The semester-long course culminates in a design expo with judging by professional engineers, the awarding of prizes to top projects, and public viewing by hundreds of folks—youngsters through grandparents—who are eager to try out the projects and learn from the creativity of engineering students. Students recognize their value as role models and respond at the highest levels. [8]

One pitfall of PBL is the lack of recognition by students themselves of the amount of learning they accomplish. Yadav et al suggests that faculty teaching a course with open-ended problems and solutions must provide effective guidance and scaffolding to support the learning process. [6] However, documentation is lacking on how instructors can craft an effective projects course learning environment. And, while everyone in an institution "knows" who the good instructors are for every engineering course, few, if any, studies have examined whether good instruction leads to greater first-year student retention. With a data set of 76 course sections taught over four years with numerous instructors, we have examined eight factors that may lead to student satisfaction and retention.

Projects Course Instructors

In project courses, there have been findings demonstrating an effect on retention, but few studies have investigated the role of the projects course instructor in retention of students. It has been the policy of the course administrators to seek out excellent instructors, but over the years there have been some variation in quality based on student feedback. Our expectation is that quality of instruction directly impacts retention and the present study delves into this expectation.

FYEP instructors come from a variety of backgrounds, as shown in Table 1.

Table 1. FYEP Instructor Backgrounds

Tenured or Tenure-Track	17	50%
Non-tenure Track	8	24%
Graduate	4	12%
Post-doctoral	2	6%
Industry, National Lab	3	9%
Total	34	100%

Nine percent are part time instructors from industry or national laboratories, 24% are non-tenured instructors and 50% are tenured or tenure-track faculty. Several instructors were current graduate students or held post-doctoral appointments. Most instructors have had some type of project-building experience gained from their own research experiences or from work outside the academic setting. Fifty percent of instructors have been women, and the ages of instructors spans 40+ years. Each year a few new to FYEP teachers join the instruction team, and numerous instructors have taught FYEP for five or more years.

There is a large variety of activities within FYEP, all of interest to and controllable to some extent by the instructor. In a typical week, an instructor may give a short lecture on engineering analysis, lead an activity to develop a first prototype, work with a team to select the best material for their project, supervise strength testing, help develop a logic diagram, and provide feedback on a report draft. As a *facilitator*, the FYEP instructor ensures that the team is not slowed by roadblocks due to lack of knowledge, equipment, or ideas, or that system issues exist. Many instructors are not experts in electronics, machining or other areas, but they know how to guide students to the experts or resources that will help them to accomplish important milestones. Also, upper-class students who have previous experience with the class serve as teaching assistants to help facilitate.

One of the most important FYEP instructor functions is as a *coach* who provides ongoing evaluations of a team's progress. Both the project progress and a team's functionality in the process may be addressed, and expectations for the deliverables are reinforced. The instructor discusses improvements and changes to be implemented, sets the project timeline and parameters and provides technical guidance that helps a team to accomplish its goal. The instructor also monitors the activities of each student to understand the distribution of project responsibilities and to ensure that new skills are learned by the entire team.

Because these are first-year students, many are not only new to engineering but are experiencing life away from home for the first time. It's important for the instructor to recognize when to step back from taskmaster roles and to show interest and caring for the students. Being a *mentor* as a FYEP instructor can be easier than for a typical lecture-style course; the small, informal classroom setting (~ 30 students) makes the instructor more accessible and easier to get to know.

In FYEP the ultimate responsibility for completing the project rests with the self-directing work team. Students recognize the freedom they have to make technical choices, how to learn to accomplish tasks, when to work, who will take on the various tasks, when to go shopping for supplies, which questions to ask clients, what information to put into reports and presentations, and a myriad of other tasks associated with a project. In this setting, the instructor must see that project milestones are met that intersect with concrete grading guidelines, so that students' efforts are fairly evaluated.

Consequently, instructors must function as project and personnel managers. Being a project versus a personnel manager requires the use of different communication styles. Project guidance needs “task” orientation, while personnel issues need are focused on “people.” In previous work [9] we discuss the distribution of four social or communication styles among a set of FYEP students: two task-oriented styles—driving and analytical, and two people-oriented styles—expressive and amiable. In FYEP courses instructors purposely create teams with a diversity of social styles. These different styles are commonly exhibited in one-on-one and team interactions. Because most people have an easy rapport with those with a similar social style, the ability to work with and value the style differences of their team members can lead students to realize that a variety of perspectives can strengthen a project. Likewise, FYEP instructors guide the actions of each team by using a variety of social styles themselves, subtly modeling the positive attributes of each. An instructor can help *drive* a project to completion and *analyze* the functionality of key components with task oriented communication. They also can brainstorm new ideas (*expressive style*) and support students through frustration or uncertainty (*amiable style*). Using all four styles means that FYEP teachers often demonstrate great versatility in their communications with students.

Sometimes the instructor works to ensure that each student experiences new skills, especially with regards to stereotypical activities. In a team setting it can be easy for the majority (typically men) to assign a stereotypical task, such as writing, to one of the women. In addition, more expressive team members can dominate team activities, effectively limiting the contributions of quieter students. The instructor then coaches the students to take on new roles and tasks. In this way, diverse students and styles — especially those who are underrepresented in engineering — can be active team members and make positive contributions to the project.

Methods

This study uses a mixed-method procedure including both quantitative and qualitative assessment methods. Participants were 76 instructors who taught sections of FYEP across four academic years.

Two assessments were used to evaluate the effect of the instructor on retention of students enrolled in FYEP courses, both assessments providing ratings from students in the course. The university’s *faculty course questionnaire* (FCQ), filled out by students in every class on campus, provides a common foundation for evaluating instructors in the FYEP courses. These FCQs are compiled by the campus institutional data group, and results are released after each semester is completed. The FCQ is an eight item survey covering different facets of the course and the course instructor’s performance. Students rate each item on a six-point Likert-type scale. FCQs are administered each semester to all classes. [10]

The second qualitative assessment is a set of focus groups composed of students in each section of the FYEP course; these interviews are coded qualitatively to develop themes related to the strengths and suggestions for improvement for each course section. [11] Retention measures into the third semester were obtained for each instructor from the campus institutional data group and correlated with FCQ ratings for each section to determine the relationship between FCQ rating and retention.

Results

Table 2 presents the mean FCQ ratings, standard deviations, and correlations with third-semester retention. The overall average across the FCQ items is 4.76 with the instructor overall rating at 4.88, both good rating averages for the College of Engineering compared with other standard first-year course ratings. For example, chemistry for engineers has an instructor overall average of 4.08 and physics I has an instructor overall average of 4.58. A standard deviation of 1.01 for FYEP instructors indicates a suitable range of responses for analysis with instructor overall ratings ranging between 1.80/6 and 5.90/6.

Table 2: FCQ Means, Standard Deviations, and Correlation with Third Semester Retention in Engineering for 76 FYEP instructors

FCQ Item	FCQ Mean (out of six)	FCQ Standard Deviation	Correlation w/Retention
Course Overall Rating	4.83	.77	.08
Instructor Overall Rating	4.88	1.01	-.01
Personal Interest Before Enrolled	4.55	.39	.21
Instructor Effectiveness Encouraging Interest	4.56	.94	.03
Instructor Availability for Assistance	4.82	.80	.05
Intellectual Challenge of the Course	4.16	.49	-.14
How Much You Learned in the Course	4.55	.55	.04
Instructor Respect/Professional Treatment	5.70	.43	.06

Qualitative focus group data backed up the overall positive quantitative results. These comments were coded into the following categories identified as strengths of the course:

- Quality of teaching: *"the best professor I've had"*
- Approachability: *"approachable…and easy to get along with."*
- Encouraging: *"lots of encouragements…"*
- Small community atmosphere: *"Comfortable atmosphere compared to engineering gulag,"*
- Allow for student autonomy: *"given responsibility for getting things done."*

Despite favorable FCQ ratings for the course, the ratings proved ultimately uncorrelated with retention with none of the correlation coefficients reaching significance ($p < .05$). The strongest correlation ($p = .06$) was with the item, "Personal Interest Before Enrolled" while the weakest correlation (p = .95) was with the item, “Instructor Overall.”

Discussion

The effort placed in selecting and training FYEP instructors has proven its worth with solid FCQ ratings across the board with special accolades to a rating (mean = 5.70) for respect and professionalism. Again, qualitative feedback bears this out with comments such as, “(teacher) is very professional and respectful.”

While the impacts of a good experience with FYEP may be helpful with some facets of students’ experiences in the College of Engineering, this experience appears to be unrelated to the third semester retention of students even though the course clearly demonstrates an impact on retention (See Figure 1). The only item that neared significance (p = .06) was students’ personal interest before enrolling in the course, which is the item least related to instruction. This is supported by previous research indicating student interest in engineering is a predictor of retention. [12] An interpretation for this lack of relationship would point to the wide variety of FYEP course components in addition to the instructor, particularly the team-based hands-on projects. Student teams are primarily self-directing with the instructor in the role of the coach and facilitator, placing a greater onus on the team and the student to provide a satisfying course experience. Qualitative focus group data support students experiences of independence in the course citing factors such as, “the room for creativity in the course,” and “the freedom to decide” as consistent strengths of the course.

Our experiences with a broad range of instructors had led us to assume a teacher effect on retention. Focus group comments for some lower-rated instructors such as, “Instructor needs to be present during class,” and “add more structure to the class…more balance, solidify deadlines” indicate dissatisfaction with the teacher. In the course sections with unpopular teachers, a heavy reliance on the teaching assistants has been noted. This seems to indicate that students manage their projects independently, regardless of teacher support.

The implications of these findings relate to the selection of FYEP instructors and the FYEP course model as a tool for improving retention in colleges of engineering. The data suggest that the “perfect” instructor does not have to be found for the FYEP course to impact retention. Previous research indicates that the highest instructor ratings on the FCQ are related to availability of the instructor when the team is needed. [10] Focus group data support these results with students providing positive feedback on instructor access and negative feedback on instructor unavailability with comments such as , “Improve the communication with us.” Thus, the FYEP model is robust enough to be imported into a college of engineering with less seasoned instructors or a smaller instructor pool.

Future research on the impact of instruction within first year design courses could focus more deeply on the reasons behind an instructor receiving low course ratings and still maintaining solid retention. Such research could be carried out at the third semester to determine the students' reasons for choosing to stay or leave engineering. Given the better results for prior student interest in this study, perhaps student factors such as self-efficacy or professional identity should also be considered for their role in retention via first year design experiences.

In conclusion, FYEP course instructors received good ratings, on average, from students who participated in their courses. Yet, these ratings did not translate to an impact on third semester retention. This leads us to consider other factors to explain the retention gains from first year design.

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