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Peer-led Team Learning in Early General Engineering Curriculum

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Abstract

The Partnership for Retention Improvement in Mathematics, Engineering, and Science (PRIMES) is an NSF STEP program being implemented across nine different departments in three different schools (Engineering, Education, and Arts and Sciences) at the University of Louisville. The cornerstone of this program is the development of Peer-Led-Team-Learning (PLTL) communities in several of the foundation courses for each of the participating departments. The underlying concept of this approach is students will feel more comfortable and are more likely to engage when mentors are closer to their same age or experience.

The exact implementation of PLTL model varies between courses, but every implementation uses an undergraduate student to present material and to provide help with homework problems. Within the courses assessed, implementation of the PLTL model has varied between using external volunteer attendance sessions versus mandatory in-class sessions. Each of these implementation styles has advantages and disadvantages. External volunteer attendance sessions allow for a better relationship between the peer leader and the attendees. The disadvantage of making it a volunteer session is reduced participation unless it is heavily incentivized. The mandatory in-class peer led groups have the advantage of greater attendance, and instant feedback on lecture materials. However, this reduces instructor led class time and can be chaotic in the classroom with multiple peer leaders simultaneously meeting in groups. It can also foster a false impression of understanding the topics, since students worked the problems correctly in a group.

Based on the J.B. Speed School of Engineering's implementation of PRIMES, the observed outcomes have been an improved attitude of students participating the program and improved student performance. Academically, students at different performance levels receive different benefits from participating in this program. Students already performing at high levels deepen their knowledge by the experience of explaining concepts to their classmates. Midlevel students benefit by having complex material explained in a variety of different formats. Ultimately, this keeps both groups engaged throughout the class. In addition to the academic gains, participating students appear to gain a greater attachment to their engineering identity and will discuss their future goals with their peer mentors.

Initial evaluation of the PRIMES program in three undergraduate departments indicates that including peer mentors in the educational process is beneficial to the student, but may be more appropriately quantified by a subtle shift in academic performance, an enlarged sense of community, and an increased commitment to their degree programs. Ultimately, these are very beneficial results, but are very difficult to quantify.

1. Introduction

The Partnership for Retention Improvement in Mathematics, Engineering, and Science (PRIMES) is a University of Louisville cross-college collaboration aimed at reducing attrition

among our STEM majors. This project unites faculty from the College of Arts & Sciences, the J.B. Speed School of Engineering, and the College of Education and Human Development in tackling identified hurdles that contribute to poor retention (and thus low graduation rates) in our respective undergraduate STEM programs. PRIMES' goals are quite simple:

1. Increase by 25% the number of Bachelor's degrees awarded in biology, chemistry, geosciences, mathematics and physics in the College of Arts & Sciences by 2016.
2. Increase by 25% the number of Bachelor's and Master's degrees in Engineering awarded in the J.B. Speed School of Engineering by 2016.

The rationale underlying these two goals is real and compelling. The University of Louisville's 2020 Strategic Plan, a business and growth blueprint for the current decade, states that we will "Implement STEM initiatives leading to more graduates with science, technology and mathematics majors; more students majoring in engineering; and an increased cohort of science teachers for K-12.". The 2020 Strategic Plan Scorecard sets year-by-year targets using 2008 graduation statistics as baseline data. University of Louisville's goal is to increase by 33% the number of degrees conferred in these disciplines by 2020. PRIMES goals intentionally mirror these Scorecard metrics for growth by mid-decade.

Evidence, both data-driven and anecdotal, indicates that we can meet our goals if the primary focus is on retention as opposed to recruitment. But evidence also shows that differences in the academic and social cultures among the various STEM disciplines will undermine a 'one size fits all' retention plan. Based upon departmental needs analyses and published research on possible 'fits' from successful STEM initiatives at other institutions, we designed PRIMES to blend two general strands that would support these anticipated outcomes:

1. Transform Teaching and Learning: Improved retention as a result of expanding our undergraduate teaching assistance (UTA) programs and institutionalizing a formal UTA training pedagogy. A working knowledge in best practices will enable them to be both effective and engaging in the laboratory and/or classroom.
2. Increase Faculty and Student Interactions: Improved retention as a result of implementing University-wide and discipline-specific (intentional) community building activities that foster STEM students' sense of identification with STEM departments.

This project's conceptual framework is built around three mutually intersecting groups: STEM faculty, STEM undergraduates, and STEM Undergraduate Teaching Assistants (UTAs). In order to strengthen retention of STEM majors, the mutually reinforcing benefits of a simultaneous focus on these three key groups will guide this project. At the heart of this triad are the UTAs, which will be the primary focus of this project's work.

The conceptual framework for the UTA implementation is based on the Colorado Learning Assistant model[1,2]. In this specific implementation, UTAs will head PLTL communities in the early core courses of the participating departments. To help foster the student to UTA mentorship, multiple UTAs are assigned to each class with a target of a 10-to-1 student to UTA ratio. UTAs are chosen by each of the departments and are typically only 1 to 2 years removed from taking their assigned course themselves. Research suggests that the learning of students in such groups benefits significantly from the mentoring of a competent peer[2–4].

Substantial numbers of STEM-intending students choose to leave STEM degree programs[5] after completing only the introductory coursework. The effective implementation of peer learning and tutorials within the introductory coursework, however, can play a significant role in preventing early departures from STEM programs[6,7]. Thus to enhance retention of STEM-intending students at the University of Louisville, our project's focus will be centered on select introductory courses for STEM majors.

Improving the teaching ability of the UTAs through direct pedagogical training will directly benefit the undergraduate students in the introductory STEM courses. Research demonstrates that mentoring from more competent peers benefits the learning of undergraduates[2–4]. Undergraduates of UTAs who underwent systematic and supported instruction in pedagogical issues regularly outscored their peers in non-UTA classes[1]. Likewise, because the presence of the UTAs and their regular interaction between the STEM faculty will strengthen the pedagogical practices of both the faculty and the UTA, and the undergraduate students in these classes will also benefit from a richer classroom experience.

This paper will focus on the implementation and early results of the UTA strand implementation within the J.B. Speed School of Engineering.

2. Implementation at the J.B. Speed School of Engineering

A very brief introduction of UTA training follows, since this paper is dedicated more to the implementation of the UTAs within the engineering school as opposed to the implementation of the UTA program. Each UTA regardless of school or department must attend mandatory workshops prior to the semester as well as a monthly seminar during the semester. The workshops have been developed with the Education Department to help train the UTAs. The workshops cover topics related to the following over a two day period:

- Questioning (closed vs open questions, also referred to as convergent vs divergent questioning)
- Preconceptions
- Mental Models
- Metacognition
- Formative vs Summative Assessments

Each seminar is designed to bring the workshop topics back into focus for the UTAs and allow them to discuss their successes and failures to date with other UTAs while being led by PRIMES faculty members.

There have been three main methods of implementing the UTAs into the classroom at the J.B. Speed School of Engineering. The methods are (a) voluntary supplemental instruction, (b) mandatory supplemental instruction, and (c) mandatory in-class instruction.

The first method, voluntary supplemental instruction (SI) model, can further be broken into two sub categories. These categories are rewarded attendance and non-rewarded attendance. The SI model has been a successful model at the University of Louisville, so using undergraduate teaching assistants (UTAs) from PRIMES was a natural extension of the model. The non-rewarded attendance voluntary SI meetings have an attendance problem. However, the non-

rewarded attendance voluntary SI meetings do not cause any grade inflation by solely attending the SI meeting. The rewarded attendance voluntary SI meeting helps counter the attendance problem, but does reward students solely showing up to the session.

The mandatory SI follows a more traditional recitation model or lab setting. Students are required to attend sessions with penalties for not attending. In the recitation or lab, students are encouraged to work on homework or assignments with a UTA available to help them with material.

The mandatory in-class instruction removes some lecture time from the faculty of record and allows the UTAs to meet with a smaller group of students to cover problems or more detailed aspects of a concept. This method combats requiring students to attend a session outside of class or having the option of attending.

2.1 Department of Engineering Fundamentals

The Department of Engineering Fundamentals has implemented the use of PRIMES UTAs using two of the previous mentioned methods. For the first four semesters, UTAs were used for Engineering Analysis I (2 semesters), Engineering Analysis II (1 semester), and Engineering Analysis III (1 semester). The Engineering Analysis courses are calculus based courses that are fundamental courses to all majors at the J.B. Speed School of Engineering. The Analysis courses average enrollment over these semesters was 230 students. These UTA sessions were all implemented with the non-rewarded attendance voluntary SI model. Each of these sessions was poorly attended, regardless of when the sessions were scheduled. The Engineering Fundamentals (EF) coordinator tried scheduling the sessions earlier in the day and later in the evening. The times did not change the average attendance being less than 3 per meeting, per UTA. Having 10 UTAs meant they only met with approximately 30 of the approximately 230 students, so this did not have a significant impact on the overall course.

Recently, the Department of Engineering Fundamentals piloted an emporium model for their Introductory Calculus course, which is a course for students that are not prepared for the Engineering Analysis I course. This pilot year allowed for the EF coordinator to try using the UTAs in a mandatory in-lab SI setting. The UTAs staffed the math lab, where students in the Introductory Calculus course were required to be in the lab working problems 150 minutes a week. The UTAs would answer questions and use what they had learned to help the students learn the material that was required for the course. This implementation obviously increased the contact hours that the UTAs had with students compared to previous semesters. The problem with this emporium model being used, is there is no way to determine if the UTAs had an impact on the course grade for the students attending the session since all of the students were required to attend lab hours.

2.2 Department of Civil and Environmental Engineering

Within the Statics class, the UTAs were incorporated into the classroom environment primarily through mandatory in-class instruction. The general format for the 75 minute class period was to have the instructor lecture and work example problems for approximately 45 minutes, and then

have the students work in small groups with dedicated UTAs. The work sessions with the UTAs could be focused on anything the students needed at that particular time. Meaning, if the students needed additional clarification regarding lecture materials, the UTAs could expand upon earlier discussions. If the students needed assistance with homework, the UTAs were able to provide guidance on solution steps or work additional example problems.

While there are many immediately apparent advantages of incorporating the UTAs into the classroom, there are some limitations.

- Classroom order and structure is very different from a typical classroom environment. The small group work necessitates student interaction and discussion, which often appears unorderly and chaotic.
- Class time during which the instructor could be leading the discussion or providing commentary to example problems is given over to the UTAs. It is not reasonable to expect that the UTAs would emphasize or highlight the same materials as the instructor.
- The UTAs must be very knowledgeable in the subject matter. A poorly equipped UTA can negatively affect a significant portion of the class.
- There has been a tendency for the students to reduce their out-of-class homework and time dedicated to the topic. Students will work on the materials during the in-class work sessions, but not review the material between lectures. As the students have been lead through example problems and "seen" problems being worked, many believe they have mastered the topic when reality may be very different.

The previous shortcomings are somewhat reflected in observed changes to the class grade distributions. The data from the summer 2012 course (114 students) was compared to conglomerated course data from 2008, 2009, 2010 and 2011 (325 students) from the same instructor at the same class time. The historical trend for the course is for approximately 27% of the students to earn A's, 33% earn B's, 23% to earn C's, 8% to earn D's and 9% to earn F's (Figure 1). For the 2012 class, there appeared to be a dramatic shift within the grade distributions from the historical trends. As shown in the Figure, 42% earned A's, 16% earned B's, 7% earned C's, 26% earned D's and 9% earned F's. Data were also compiled for the same Statics class in the summer of 2013 (148 students). These data indicate a return to the more typical grade distribution as 23% earned A's, 30% earned B's, 20% earned C's, 22% earned D's and 7% earned F's.

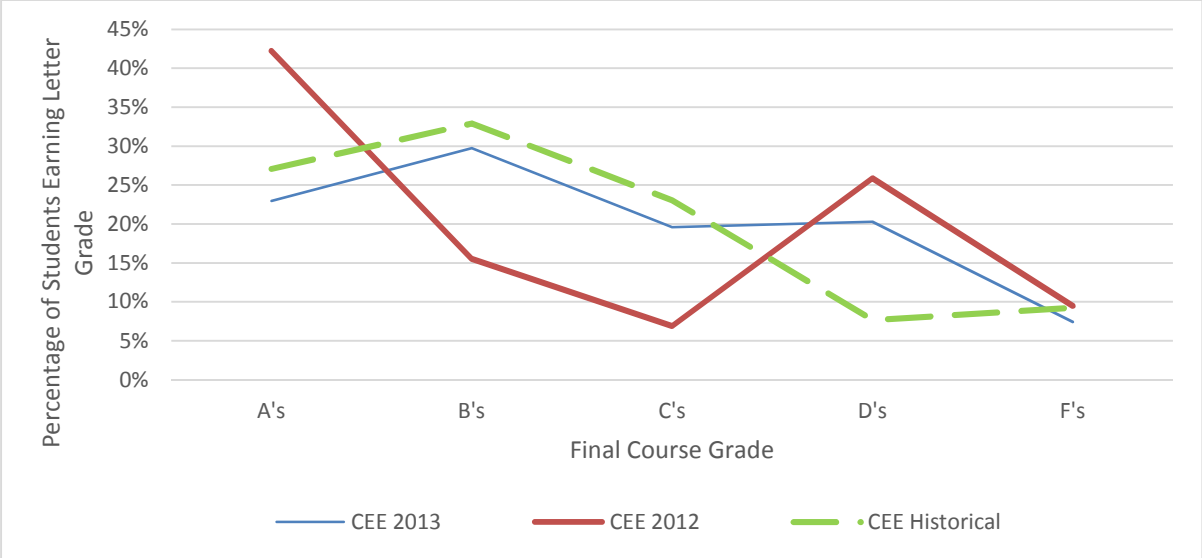

Figure 1: Grade Distribution Associated with UTAs Mandatory In-Class Instruction

The grade distributions from the two separate implementations of the UTAs within the Statics class present two very different outcomes. The 2012 data shows a dramatic effect of incorporating the UTAs into the teaching environment. The marked shift from B's and C's to A's (or D's) is significant and was not evident in any of the historic data. Thus, the UTAs may have been effective in helping students gain a deeper understanding of the material and thus perform at a higher level. Students that generally would have earned B's and C's were now performing at a higher level. However, it is also noted that a higher than typical percentage of the students also earned D's. This could be due to the students adopting a false sense of achievement as their homework assignments were generally completed with UTA assistance and not from individual mastery of the materials. Several students did comment that their out of class preparation time reduced as it was easier for them to wait for the UTA session rather than struggle with the problems individually.

The grade distribution data for the 2013 statics class that incorporated the UTAs appeared to return to a more typical grade distribution. When assessing this trend, two possible influences were noted. First, when reviewing course evaluations, several students commented that the caliber of the UTAs was not up to their standards. Of the 13 UTAs involved with the course, several did not exhibit an aptitude for teaching and others did not display sufficient mastery of the materials. While the majority of the student comments were complementary of the UTAs, several expressed concerns or discontent. A sampling of the negative comments follows:

- *SCREEN THE UTAs. Some seemed clueless and couldn't help while others were extremely helpful and knowledgeable.*
- *Make sure the UTA's know what they're talking about.*
- *This course was a very well organized and taught course! However, I got the sense that a couple of the UTA's had zero interest in being there and were not very helpful when we asked them questions about one of the problems we were working on.*
- *Breaking out into TA groups was not very helpful. The TA in my section never knew how to do the problems or had the right answers so it was not beneficial at all. If this is going to be continued, better TAs need to be chosen and they need to have the correct answers.*

- *Some UTA's were great, some were not at all good.*

Thus, there may have been a significant change in UTA quality between the 2012 and 2013 classes. Second, there is a tendency to recalibrate grading metrics based on current information. When students perform better, our expectations for their abilities also rise. Thus, the return to more traditional grade distribution may be due to a normalization of grades based on the previous years' experience.

2.3 Department of Chemical Engineering

Implementation of the UTA strand in the Department of Chemical Engineering has focused on the first three courses students will take within the department, namely Introduction to Chemical Engineering, Introduction to Materials Science, and Material and Energy Balances. In each of these courses, the UTAs lead a voluntary Supplemental Instruction session that occurs outside of normal class time. This implementation has had varying levels of success in each of the courses.

The most successful implementation has been within the Introduction to Materials Science course where attendance is heavily rewarded by extra credit towards the student's final course grade if they attend at least half of the offered sessions. This has led to an 83% attendance rate over the two years of implementation. The Introduction to Chemical Engineering course where participation is not incentivized has seen a 50% attendance rate. The lower attendance is mainly attributed to the perceived ease of material in the course. The freshman that do attend the sessions though are interacting with Junior and Senior UTAs in a true mentor-mentee relationship in charting their course through their degree program. The Material and Energy Balances course has the lowest attendance of the three, bordering on the 10% to 20% range. As with the Introduction to Chemical Engineering course, participation in the SI session is not incentivized. Additionally, the students are required to attend a recitation section offered once a week. Because of the amount of time spent in the course already, students are unwilling to attend another session on a voluntary basis with little perceived benefit.

In addition to these sessions, both the Introduction to Chemical Engineering and Material and Energy Balances courses also have the UTAs participate in mandatory in-class instruction sessions. The in-class instruction for the Introduction to Chemical Engineering course comes at the end of the semester during a design laboratory where students are asked to reverse engineer an automatic drip coffee maker. For the Material and Energy Balances course, the UTAs are responsible for helping students during the mandatory recitation section for the class. This usually comes in the form of help solving example problems being worked during the session or help with developing their excel spreadsheets.

Based on the attendance, studies on the impact of the UTAs on student learning have focused on the Introduction to Materials Science course. This particular course is offered during the 10 week summer session. The students mainly come from three different engineering departments (Chemical, Industrial, and Mechanical Engineering) and range from freshman to graduating seniors. Enrollment in the course has steadily increased over the past five years forcing the course to move from a 50 person classroom to a 250+ person auditorium. The average final exam score though has decreased significantly over the same time period, as seen in Table 1.

Table 1: Enrollment and Final Exam Score for Introduction to Materials Science

Year	Number of Students	Average Final Exam Score (150)
2008	46	125
2009	61	123
2011	75	122
2012	89	122
2013	98	117

Peer-led SI sessions were introduced in 2012 and based on the bulk data, it appears as if the UTAs are having a negative impact on the course. Digging down into the data presents a slightly different picture though. It was assumed that students needed to attend at least half of the SI sessions to have an impact on student learning. Based on this assumption, students who attended half or more of the SI sessions were compared to those who attended less than half the sessions. As can be seen in Table 1, there wasn't a statistically significant difference between the two groups in 2012 suggesting that the UTAs didn't have a negative impact in the course. The story is much different in 2013 as there is a significant difference between the two groups where those who attended at least half of the SI sessions (80% of students) outscored their counterparts by 13 points on a 150 point exam (P value of 0.0265 in an unpaired t-Test). At this time, it is unclear as to why there was a drop-off in final exam scores between 2012 and 2013, but work is currently being done to examine the students in each of the years more closely based on grades in the pre-requisite course (General Chemistry 2) and time between the two courses.

Table 1: Comparison of Final Exam Scores Based on SI Session Attendance

Year	Number of Students	Average Final Score	Attended less than half SI	Attended more than half SI
2012	89	122	125	122
2013	98	117	104	118

3. Conclusions and Future Directions

Based on the early results of this program, it can be seen that UTAs are not having negative impact on their students and, in some cases, are clearly beneficial. These benefits are not only in the form of improved student performance in the course, but also through the development of a mentor-mentee relationship. The key aspect lies in assuring that the UTAs and the students have regular contact, and this is not an issue for the mandatory SI sessions. For the voluntary sessions, however, the students seem to attend only when there is a reward. If there is only a "perceived" reward in the form of a better grade, or if the perceived contact time for the course is high, students are less likely to attend the sessions and thus do not gain any benefits from the UTAs.

PRIMES is very early in its implementation, and there are a large number of research initiatives that have yet to be started. Several of these initiatives focus on the students of the courses. Specifically, attempts will be made to normalize students based on their performance in pre-requisite courses, grade point averages, and other standardized measures to gain a better assessment of the students. Students will also be tracked as they matriculate through their degree program to determine if the UTA exposure early in their curriculum has a lasting impact on

retention and performance. It is anticipated that repeated exposure to UTAs in the classroom environment will help better engage the students throughout their curriculum.

The UTAs are also an important study group within this program as one of the aims of the project is to increase the UTAs depth of content knowledge and determine the impact of the UTA experience as they matriculate through their degree program. The UTAs will be tracked through their curriculum to determine if this has an impact in their advanced courses and their future career paths. It is anticipated that the deeper understanding of the materials gained by being a UTA will entice them to take more rigorous courses as they matriculate. It is possible that the teaching experience may influence them to pursue an academic career at either the primary, secondary or collegiate levels.

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