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Research and Instructional Strategies for Engineering Retention

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Research and Instructional Strategies for Engineering Retention

The Research and Instructional Strategies for Engineering Retention (RISER) was funded by the NSF STEM Talent Expansion Program (STEP) in July of 2011 and has focused on two specific undergraduate populations within the University of Tennessee, Knoxville (UTK) College of Engineering (COE) where retention was low. Both groups were freshmen, specifically: 1) freshmen who do not qualify for the freshman Engineering Fundamentals (EF) program due to ACT math scores of 27 or below and 2) freshmen women students in any of the various honor programs. RISER interventions have worked to improve the freshmen experience for these groups with the goal of increasing the early retention and ultimately the graduation rates for these at-risk students. Interventions have included: 1) engineering only sections of precalculus with visits from engineering faculty and/or students and an optional RISER Living Learning Community (LLC) for freshmen with ACT math scores of 27 or below; 2) a summer preparatory academic/community camp for students with math ACT scores of 27 or 26 encouraging them to take and pass the math placement test, enabling immediate entry into Calculus I and Physics for Engineers I (EF); and 3) RISER Undergraduate Research Assistantships (URAs) for the women honors students.

Introduction - RISER program interventions for improving early retention

Retention of freshmen female engineering students associated with any of the honors programs, or taking the honors version of EF, was a concern at the time the proposal was submitted. In 2010 this group was low in total number but the percentage of these women leaving engineering during their freshmen year was high. The PI's believed that one reason for this was that most of these young women were concerned about their career path having a clear connection to being beneficial to society. The RISER URA program was initiated for these students to build mentoring relationships with faculty members, senior researchers, graduate students, and other undergraduate students doing research, to connect current advances in science and technology to their academic coursework, and to promote an understanding of how research in their engineering disciplines can be intellectually challenging, personally satisfying, and beneficial to society. In the Fall of 2011, the first RISER URA's were recruited and started their research in the Spring of 2012. The RISER program funds the students at $10/hour for about 10 hours/week during their freshmen academic year. Then the summer between their freshmen and sophomore years they can work up to 40 hours/week. If the RISER URA stays with the program into their sophomore year they get a raise, to $12/hour, and can work about 10 hours/week during their second academic year. They are encouraged to present their research at both internal and external events and to participate in professional conferences and if appropriate, RISER will sponsor either full or partial travel costs.

RISER math camp has been provided to interested incoming engineering students with math ACT scores of 26 or 27 every summer since 2012. The campers move in on a Sunday and the camp continues for ten days (through the first week and up to the Wednesday of the next week) and is offered just prior to the beginning of the Fall semester. This allows the students to move directly into their assigned dormitory rooms at the conclusion of camp. The camp is designed to both invigorate their math skills for passing the math placement test, offered online by the Math Department and focusing on precalculus skills, and to provide them with a preview of university

life. During the years of the camp, several observations were made including how exact the input format for answers into the math placement test needs to be and that most of the students had just finished high school calculus their senior year and their precalculus skills were unpracticed. The daily weekday organization of the camp included roughly 4 hours/day focused on precalculus taught by a lecturer from the math department. The university life aspect of the camp included visits to locations or from staff members representing various support organizations including the library, Student Success Center, Tennessee Recreation Center for Students, and the Center for Leadership and Service, and the COE offices of Engineering Professional Practice to discuss co-op opportunities and Engineering Advising Services (EAS). Faculty from various engineering departments, including EF, visited the campers and often joined them for lunch. Every year there was an off-site visit to a low ropes course, for character and community building, that was extremely popular with the students. Minimal activities were organized over the weekend allowing the campers to catch up on sleep, study, and use at least one of their three attempts at passing the math placement test. Passing the online math placement test promoted them out of an at risk group and allowed the students to start Calculus I and the Physics for Engineers I in the Fall of their freshman year, rather than precalculus, and put them a semester or summer session closer to their degree. The goal was not only that these students passed the math placement test but also that they were successful in their calculus and EF series as well as throughout their academic career.

Starting in the fall of 2012 engineering only sections of precalculus were offered. Prior to these sections of "RISER Precalculus" entering COE students with a math ACT score of 27 or below had no organized interactions with COE faculty or other COE students. During this first semester they were encouraged to take classes fulfilling their general education requirements, English Composition, and possibly General Chemistry I in addition to precalculus. If they passed precalculus then they could take Calculus I and Physics for Engineers I in the Spring putting them one semester behind. Data from 2009 forward shows that about a quarter of the entering COE freshmen need precalculus their first semester. This has remained constant despite freshmen cohort size rising by about 65% from 2009 (459 entering freshmen) to 2014 (767 entering freshmen). The first Fall (2012) RISER precalculus was offered, there were four sections taught by two different lecturers, covering two sections each, from the Math Department. During the first year scheduling conflicts occurred but have been resolved so that in subsequent years close to 100% of the freshmen COE students that needed precalculus were in RISER sections. With more incoming students the number of sections needed to be increased from four to five for the subsequent years.

In addition to getting the freshmen COE precalculus students together in sections, Dr. Richard Bennett, the Director of Engineering Fundamentals (EF), visited the various sections periodically at approximately two-week intervals. During these visits Dr. Bennett gives a short example connecting what the students are currently studying in precalculus and how it relates to engineering. Examples of applications covered and some preliminary results on the first year of RISER precalculus were presented at the American Society for Engineering Education (ASEE) Annual Conference and Exposition in 2013[1]. In subsequent years, the topics and applications have been related to different engineering disciplines and engineering challenges. Details are available for others to use from the RISER website http://ef.engr.utk.edu/RISER/ by following the precalculus tab and then choosing a year.

A RISER Living Learning Community (LLC) is available for the students with math ACT scores of 27 or below. The RISER LLC was offered to incoming freshmen during the 2012-2013, 2013-2014, 2014-2015, and 2015-2016 academic years and about 18%, 16%, 14%, and 24%, respectively, of the students eligible to live in the RISER LLC did so these years. During the first two years the RISER and the Engage (students taking Calculus I and Physics for Engineers I their first semester) LLCs were house in separate dormitories, however, for the last two years the RISER and Engage LLCs have been together. The RISER/Engage community has a LLC Peer mentor who resides with them and focuses on how to guide these new students toward successful academic and social transitions into the university environment. Over the course of the four years changes in housing and EF staff have resulted in more organized involvement and more social events in the two COE LLCs.

Program outcomes

The RISER program outcomes reported here are mostly based off of a report generated by the University of Tennessee Office of Strategic Enrollment Reporting and Analysis (SERA), run in early December 2015. The report provided copious amounts of data on the students that started their academic careers in the COE. To understand the number of total COE students, students that took precalculus their first semester, and students that continued in COE disciplines, the spreadsheets were sorted on various criteria. Retention was determined by the student continuing to major in a COE discipline or undeclared engineering. The length of their retention was determined by the last semester their major was in one of the various engineering disciplines or undeclared engineering. This report was used mainly to track the precalculus students since this group was by far the largest (approximately 150/year). The RISER Campers, URAs, and LLC students were low enough in number, approximately 150 over the length of the program, that the RISER PIs and RISER Coordinator periodically look up these individual students to track their progress and intervene when needed and possible. For a variety of reasons the tracking of these students is not a trivial task. Complications include not being able to tract the students progress once they leave the COE and/or in some cases the University of Tennessee. Additionally if the student is away on a co-op, internship, or study abroad experience it is often not noted and can be mistaken for a student transferring out that semester. Trying to pick a constant for tracking these students has been difficult. Ideally graduation percentage would be the best indicator of success for the RISER program but many students do not graduate in four years, especially if they participate in enriching programs such as co-op opportunities and/or study abroad. Additionally if graduation percentage were used the results would only be able to be assessed after the conclusion of the program and more timely understanding of retention allows us to adjust interventions for better success. At this time, only the first year RISER URA's, entering during the 2011-2012, have passed the four-year graduation date.

For the academic years 2011-2012, 2012-2013, 2013-2014, and 2014-2015 151 female engineering students were designated as honor students and have been eligible for RISER URAs with about of third of those eligible having participated. Retention of students that have participated in the RISER URA program has been greater than 85% and interviews with several of those that have transferred out of engineering indicate the students are remaining in STEM fields including biology and earth sciences. In the fifth year of the program five of the six

undergraduate research assistants recruited in the Fall of 2011 have graduated, the one that has not graduated participated in an industrial co-op. By the Spring of 2016 a second set of RISER URA's are on target to graduate. Of ones that have graduated, the majority graduated with either summa cum laude or cum laude distinction and many that have graduated are continuing on in graduate studies in their engineering discipline.

The students and faculty that participated in the RISER URA program are both enthusiastic about the program. Many of the RISER URAs are ambitious and vocal about how their early research involvement with RISER set the foundation for future research experiences, including participating in Research Experiences for Undergraduates (REU) and other external programs both at other universities and national laboratories, studying abroad, and earning accolades both internal and external to UTK.

In the Fall of 2011 only 20 women were eligible to be RISER URA's, however, over the years the RISER program has been in existence at UTK the number of incoming female COE students associated with the various honors programs has sharply increased to 67 in the Fall of 2015. In recent years the COE has established a new Engineering Honors Program with a new Director of Engineering Honors. This new program is focused on offering experiential learning experiences and is offering a Grand Challenges Scholar Program aligned with the National Academies of Engineering Grand Challenges.

Over the four summers the RISER Camp has been offered, fifty incoming COE students have participated, two of those had previously placed into calculus but asked to attend the camp to refresh their math skills and participate in the university life series. Forty-six of the forty-eight or 96% of students needing to pass the math place test passed. Two students did not use all three of their attempts to pass the math placement test and voluntarily stayed in precalculus. Both of these students are still majors in a COE discipline. For students that attended the first RISER Camp in 2012, their four-year target graduation date is Spring 2016, however, several of the students have participated in co-op experiences resulting in an expected graduation date of Spring 2017. The average of the retention for the 2012, 2013, and 2014 campers is close to 60%.

Over the years we have been able to reduce the cost per camper from approximately $2500 in the first year to just over $1000. Changes that helped to reduce the costs included downsizing from three counselors in the first year to two in the subsequent years (with the exception of the first year counselors were RISER camp alumni), eliminating an English skills activity and associated lecturer, and nightly dinners. For the latter it was discovered the first year that the students selected to eat off campus so in the subsequent years dinners, except for a welcoming and closing dinner with the Dean or special guest, were eliminated. During the first year the students lunches were covered in the dining hall but in the subsequent years the lunches were catered and students ate in a COE classroom with various visiting faculty.

Despite the fact that the students that participated in RISER camp are extremely appreciative and enthusiastic about their experience, the largest challenge we faced over the four years was recruitment. The RISER program only requested a $50 commitment fee and provided the lectures, activities, housing, and most meals free of charge removing any financial burden for attending. However, the four-year average of incoming freshmen attending the camp was only

about twelve per year and we were prepared to offer spaces for double that amount. Information about RISER camp was distributed in orientation packages to students scheduled to take precalculus their fall semester. Parents were also informed about RISER camp and advantages about participating. Information from the flyer that was placed in the orientation packages is included at the end of this paper in Appendix 1.

Table 1 shows the number of RISER sections, math lecturers, and total number of COE students needing precalculus for each academic year RISER Precalculus has been offered. In the first year scheduling issues limited the number of engineering students that could participate so that only about 70% of the eligible students enrolled in RISER sections while in latter years the enrollment has increased to well above 90% of the eligible students. In later years once all the engineering students have registered, the Math Department has opened the sections to non-engineering students. The amount of non-engineering students is 10% or less of the total enrollment of the sections.

Table 1. Number of RISER sections, enrollment, lecturers, and COE students needing precalculus each academic year.

Academic Year	RISER			COE Students Needing Precalculus
	Sections	Enrollment	Lecturers	
2012-2013	4	96	2	140
2013-2014	5	146	3	165
2014-2015	5	165	3	176
2015-2016	5	154	4	144

Table 2 summarizes graduation and retention of COE students entering between and including the Falls of 2009 and 2014. Using data on COE freshmen entering in the Falls of 2009 and 2010, years prior to the RISER program, allows for recent historical graduation percentages to be established. About 54% of the COE freshmen entering in Fall of 2009, with a four year graduation date of Spring 2013, have graduated with less than 1% left in the program. Breaking graduation percentages down to students that needed precalculus and those that could start in Calculus I and Physics for Engineers I, shows a much lower graduation for the former group (35%) compared to the latter group (61%). The results for freshmen starting in 2010, with a four-year graduation date of Spring of 2014, are similar and again show a higher percentage of students graduating for the group of students taking Calculus I and Physics for Engineering I in the Fall of their freshmen year compared to students starting in precalculus.

Table 2. Graduation, second semester, and year two retention percentages for COE students entering between 2009 and 2014.

Entering Fall	2009	2010	2011	2012	2013	2014
Four Year Graduation Spring	2013	2014	2015	2016	2017	2018
Total Graduated in an Engineering Discipline by August 2015	54%	49%	24%	N/A	N/A	N/A
Not Graduated but on Track to Graduate in an Engineering Discipline	>1%	5%	35%	N/A	N/A	N/A
EF Graduated in Engineering Discipline[1]	61%	57%	30%	N/A	N/A	N/A
Non-EF Graduated in Engineering Discipline	35%	22%	28%	N/A	N/A	N/A

Total Retention into Second Semester	87%	87%	90%	89%	89%	86%
EF Retention into Second Semester	87%	88%	89%	90%	91%	86%
Non-EF Retention into Second Semester	88%	83%	91%	85%	83%	84%
Total Year 2 Retention in COE	75%	73%	76%	73%	79%	74%
EF Year 2 Retention in COE	78%	76%	78%	77%	83%	76%
Non-EF Year 2 Retention in COE	66%	62%	70%	60%	64%	65%

[1]Percentage calculated by the number of each group (i.e. EF or non-EF) divided by the total number for each group.

Graduation numbers for students starting after the RISER precalculus program came into existence are unavailable so retention into the second semester and year two have been tracked and are given in Table 2. Second semester retention for freshmen that start in Calculus I and Physics for Engineers I (EF) is generally in the upper eighties or low nineties compared to the precalculus (non-EF) second semester retention that shows more scatter over the years and is slightly less. Total year two retention in COE is generally in the mid-seventies. Breaking down into freshmen that start in Calculus I and Physics for Engineers I and freshmen that start in precalculus, shows that COE retention into year two is in the upper-seventies for the former group and mid-to-low sixties for the latter. These results suggest that about 10% of the students that leave the COE do so after the first semester and an additional 15% leave after their second semester while the remaining 20% leave after starting their second year. The retention for both groups appears to be relatively flat compared to tracking results provided by Engineering Advising Services focused on enrollment of precalculus students into either Physics for Engineers I (EF 151) or Introduction to Physics for Physical Science and Mathematics Majors I (PHYS 135) that replaces for Physics for Engineers for Computer Science students. Enrollment in EF 151 was about 60% for precalculus students prior to the RISER program and closer to 70% since the RISER precalculus intervention has been in existence. At the current time the PI's are trying to understand the discrepancies. Observations of this precalculus group by the PI's and the math lecturers that teach the RISER precalculus include that the group is made up of two very different divisions of students: students that really should be enrolled in calculus and have no trouble with the precalculus class and students that struggle in precalculus and will continue to struggle in math and engineering courses.

Despite the flat results shown above many associated with the EF or RISER programs believe the RISER precalculus sections are improving the freshmen experience for students that must take precalculus their first semester. After the seeing these results the PI's are working out details for future RISER precalculus students to take part in a hands on activity next Fall in the newly established COE Innovation and Collaboration Studio (ICS). The ICS is a "maker space" and when fully operation it will house a variety of 3D printers along with traditional manufacturing equipment.

Challenges for the precalculus component of the RISER program include working with the Math Department to schedule the sections and assign lecturers. In fairness to the Math Department they are trying to balance workloads of lecturers and fill sections to high demand courses that are required for multiple majors. Additionally, the RISER sections are attractive to the lecturers in the math department since these sections often have higher performing students than the non-RISER sections. The latter observation is in part based on discussions between the RISER PI's

and math lecturers and is supported by comparing the common final exam average for RISER and non-RISER students that has been about 6-10 points higher for the three years it has been reported.

Retention percentages for RISER LLC students during the incoming freshmen years of 2012-2013, 2013-2014, 2014-2015, and 2015-2016 are 63%, 41%, 78%, and 90%, respectively. The latter years will most likely decrease with as more years pass. Two observations can be made from analyzing the students participating in the RISER LLC. One, that participation is increasing and two, combining the RISER and Engage LLCs had a positive influence on the RISER students advancing in COE.

Conclusions

Since the existence of the RISER program in the UTK COE, greater than 600 students have participated in RISER interventions. Over the years those organizing the various activities have identified ways to make the RISER program more efficient and cost effective. As retention and graduation results are starting to become available the PIs are looking for additional experiential activities to offer at risk students. In the case of the RISER Precalculus students, the group has two distinct factions, those that are quite capable of succeeding in precalculus and later technical courses needed to graduate in an engineering discipline and those that will struggle with precalculus and through out their academic career.

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References

1. Bennett, R.M., Russell, M.H., and Rawn, C.J. (2013). "Engineering Introduction in Pre-Calculus Courses." Proceedings, 2013 ASEE Annual Convention, Paper 5386.

Appendix 1. Why attend RISER Camp?

RISER Camp is a great way to prepare for the Math Placement Test Level 4. By passing the Math Placement Test Level 4 you can move up from Precalculus (Math 130) into Calculus (Math 141).

(Incoming Student) Can't I just pass the Math Placement Test on my own? I have three attempts, right?

(RISER) Yes, of course. However, check this out:
In a given year approximately 12% pass the test when they take it for the first time.
Taking in account that you have three tries to take the Math Placement Test the overall pass rate is only about 50-60%.

Even if passing the Math Placement Test isn't your priority RISER Camp is a great math review prior to starting classes in the Fall.

(Incoming Student) Math review?! Right before I start my freshmen year, uggghhh!

(RISER) RISER Camp also has a College Life series where we introduce students to the Student Success Center, Library, the Office of Professional Practice, etc. We even do an off campus ropes course emphasizing team work, when to ask for help, etc. The students stay in the dorms and learn about riding the T, eating on campus, and in the evenings students get the chance to explore campus offerings such as the TRECS. You start out a little more familiar with the campus and what is expected of you in the upcoming months.

(Incoming Student) Okay, it is sounding better. Tell me more.

(RISER) If you start out in the Fall in precalculus, you cannot start your Engineering Fundamentals sequence until the Spring semester since Calculus is a corequisite for the first Engineering Fundamentals course. This means either summer school to get caught up or an additional semester.

Let's not candy-coat it. Engineering is a challenging major. You probably love science and math and are looking for a major that contains those elements that intellectually challenge you and you will be able to turn your education into a well paying job and career. If you start out in precalculus and getting a bunch of general education credits out of the way your first semester is not going to be that challenging. Then in the Spring – BAM – now you have Calculus and Engineering Fundamentals and any bad habits you slipped into during the Fall . . . . Need we say more?

(Incoming Student) I get the picture. It would really benefit me and get started out on a better footing and I would be more likely do well my freshmen year in Engineering leading to my eventual goal of graduating with an Engineering degree.

(RISER) One last nice perk – you get to move into your dormitory room early! If you have older brothers or sisters that your parents have previously helped move in during the regular move in hours they will really appreciate this last bit of information. On normal move it day campus is mobbed!