

AC 2007-1266: AN INNOVATIVE METHOD TO REALISTICALLY TRACK ENGINEERING STUDENT RETENTION AND ACADEMIC PROGRESS

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An Innovative Method to Realistically Track Engineering Student Retention and Academic Progress

Accurate data about student persistence (retention) and academic progress, particularly for first-year and lower division students, is essential to understanding and addressing factors affecting student success in engineering. Unfortunately, nationally standard methods of measuring freshman persistence and graduation rates provide an incomplete, and in some cases inaccurate, picture of engineering student retention issues. Standard assessment methodology is based on a simplistic model of higher education – the expectation that freshman enter a university, choose a major, attend full time, and emerge four to six years later from that same university with a degree. All other students – those who transfer into or out of a university, those who work off campus and attend college part-time, those who take a semester off for personal, military or financial reasons – are not included in the standard model or the reported statistics.

In today's higher education environment where 60% of "Millennial" students attend more than one institution, this simplistic model is becoming outmoded. And in our metropolitan university that provides educational access to a wide range of students – where many of our engineering students arrive on campus needing preparatory coursework in math, where almost all students work off campus, and at least 40% attend college part time – the standard model becomes ineffectual.

To better understand factors affecting persistence and success in our student population, our team developed a model that measures retention and academic progress of all engineering students. Additionally, our team focused special emphasis on freshman level students. Unlike the rigidly linear model described above, our model recognizes multiple entry and exit points and differing rates of progress along the route of engineering education. Over three academic years, our team developed and refined an algorithm to query the university database and ask meaningful questions about our students and their progress. In our algorithm:

- Students are classified (pre-freshman through senior) based on their level of completion of the curriculum in each engineering department, rather than based on university credits.
- Retention and academic progress of all engineering students, regardless of transfer status or part-time enrollment, is considered when tracking student graduation and progress.
- Progress through the curriculum is analyzed through the filters of gender, ethnicity, socioeconomic status, age, level of math preparedness, and other parameters.

In this paper we will explain how our model and algorithm have provided greater clarity on retention issues and trends affecting pre-freshman and freshman level engineering students. The data prompted our engineering college to respond in several ways, such as creating a new introductory engineering class for pre-freshman level students, enhancing emphasis on advising, and supporting math education through a variety of programs. We will also explain how the sorting algorithm is a method easily adaptable and portable to database systems at other universities.

An Innovative Method to Realistically Track Engineering Student Retention and Academic Progress

Abstract

Accurate data about student persistence (retention) and academic progress, particularly for first-year and lower division students, is essential to understanding and addressing factors affecting student success in engineering. Unfortunately, nationally standardized methods of measuring freshman persistence and graduation rates provide an incomplete, and in some cases inaccurate, picture of engineering student retention issues. Standard assessment methodology is based on a simplistic model of higher education – the expectation that freshman enter a university, choose a major, attend full time, and emerge four to six years later from that same university with a degree. All other students – those who transfer into or out of a university, those who work off campus and attend college part-time, those who take a semester off for personal, military or financial reasons – are not included in the standard model or the reported statistics.

In today's higher education environment where nearly 60% of students attend more than one institution¹, this simplistic model is becoming outmoded. And in our metropolitan university that provides educational access to a wide range of students – where many of our engineering students arrive on campus needing preparatory coursework in math, where almost all students work off campus, and where at least 40% attend college part time – the standard model becomes ineffectual.

To better understand factors affecting persistence and success in our student population at Boise State University in Boise, Idaho, our team developed a model that measures retention and academic progress of all engineering students. Additionally, our team focused special emphasis on freshman level students. Unlike the rigidly linear model described above, our model recognizes multiple entry and exit points and differing rates of progress along the engineering education route. Over three academic years, our team developed and refined an algorithm to query the Boise State University PeopleSoft database and ask meaningful questions about our students and their progress. In our algorithm:

- Students are classified (pre-freshman through senior) based on their level of completion of the curriculum in each engineering department, rather than based on university credits.
- Retention and academic progress of all engineering students, regardless of transfer status or part-time enrollment, is considered when tracking student graduation and progress.
- Progress through the curriculum can be analyzed through the lenses of gender, ethnicity, socioeconomic status, age, level of math preparedness, and other parameters.

In this paper we will explain how this model and algorithm have provided greater clarity on retention issues and trends affecting pre-freshman and freshman level engineering students at Boise State University. The data prompted our engineering college to respond in several ways, such as creating a new introductory engineering class for pre-freshman level students, enhancing emphasis on advising, and supporting math education through a variety of programs. We will also explain how the sorting algorithm is a method easily adaptable and portable to database systems at other universities.

Background: Standard Measurements of Student Success

Engineering colleges at metropolitan public universities such as Boise State University provide affordable access to education for a diverse population of capable students, from National Merit scholars seeking an urban college experience to non-traditional students balancing family, work and education. Quantifying overall student success into one or two indicators can be tricky in such a non-homogeneous population, where some first-year students arrive with a year's worth of advanced placement credits, including calculus, and others arrive with ambition and dreams, but algebra-level preparation.

How is student success traditionally quantified? Two of the most oft-reported national measures of higher education institutions are: 1) persistence (retention) of first-time, full-time freshmen, and 2) six-year graduation rate of students who started and finished at the same university. As students are central to this discussion, here are descriptions of four typical engineering students at Boise State University, a public metropolitan university. (Names have been changed to protect their identities.)

- **Stefano** entered college as an engineering major full of hope and ability but lacking in adequate preparation. He attended full time for three semesters but then slowed down his academic progress as he had to work to support his family. He graduated from the university more than eight years later as a capable engineer with a great job offer.
- **Valerie** was a freshman and military reservist when the Iraq War began. After her first semester she was called up for a tour of duty, and returned to college three semesters later and resumed her engineering studies. She is now a sophomore doing well in her classes.
- **Jim** declared an engineering major for two years but struggled with math and later changed his major. He is on track to graduate with a business degree in five years.
- **Lucy** transferred to the university from a community college her junior year. She got involved as a student researcher and student leader and graduated five semesters later with several awards and multiple engineering job offers from prestigious corporations.

Which of the above students would be deemed a positive measure of student success according to both standard indicators? The answer is: only Jim, the student who changed his major to business. Stefano would reflect negatively on the university's six-year graduation rate. Valerie would reflect negatively on the freshman persistence (retention) rate, even though she returned after her tour of duty. And Lucy wouldn't count as a success in either statistic, as she transferred in from a community college!

Students like Stefano, Valerie and Lucy don't fit neatly into the traditional model of higher education where a student completes high school, immediately enters college on a residential campus, declares a major, and has adequate academic preparation and financial resources to emerge, diploma in hand, four to six years later from the same university. At a metropolitan university such Boise State, it's likely that the majority of the student population is not included in the data source for those standard indicators.

As the university profile in Table 1 shows, only 12% of the Boise State University undergraduate population is comprised of first-time, full-time freshman. The profile also shows that 1,080 incoming degree-seeking students this fall were transfer students, who are not included in retention and graduation rates, and 686 were readmitted degree-seeking students, such as Valerie, who left for one or more semesters for personal or financial reasons. Approximately 9% of the university's students are engineering majors. Also of note, 67% of the undergraduate degree-seeking students receive federal financial aid. The university serves a large population of students classified as lower income and who reported themselves as first-generation degree-seekers.

Table 1: Boise State University Undergraduate Profile: Fall 2006

Undergraduate enrollment	16,017
% of degree-seeking undergrads receiving federal Title IV need-based assistance (grants, work-study, federal loans, etc.)	67%
% students attending full time	61%
First-time, full time freshmen	1,922
% of undergrad population who are first-time, full-time freshmen	12%
New transfer students – degree seeking	1,080
Returning students – degree seeking (who left for one or more semesters)	686

The university does not track the number of students who transfer to other institutions, so all students who transfer elsewhere are considered the same as drop outs, even if they obtain a degree from another institution. U.S. Secretary of Education Margaret Spellings and other advocates have proposed a national data base that would track students universally – an idea that might provide useful information but has raised concerns about privacy rights.²

Over the past four years the first-time, full-time freshman retention rate for Boise State has averaged 69% for engineering students and 62% overall, as compared with a current 69% national average of all higher education institutions.³ The six-year graduation rate hovers around 27-29%, compared with 55% nationally.⁴ The traditionally lower graduation rate at public metropolitan institutions is largely reflective of the mission to provide broad access.

Utilizing the first-time, full-time freshman retention rate and six-year graduation rate as indicators gives a wide-angle snapshot at one entry and one exit point in the university system. Boise State's team set out in 2003 to zoom in and create a more detailed picture of student experience by assessing year-to-year progress of engineering undergraduates and including the large population of students who transfer in or return after a time away. The team was comprised of faculty and staff from the College of Engineering and from the university's institutional analysis department. Funded by a grant from the William and Flora Hewlett Foundation's Engineering Schools of the West Initiative, the ultimate goals of the project were to gain a more thorough understanding of student success factors and to use the data to suggest curricular and programmatic improvements. Coming full circle, these programmatic improvements should eventually affect first-time, full-time freshman retention and six-year graduation rates.

A New Model

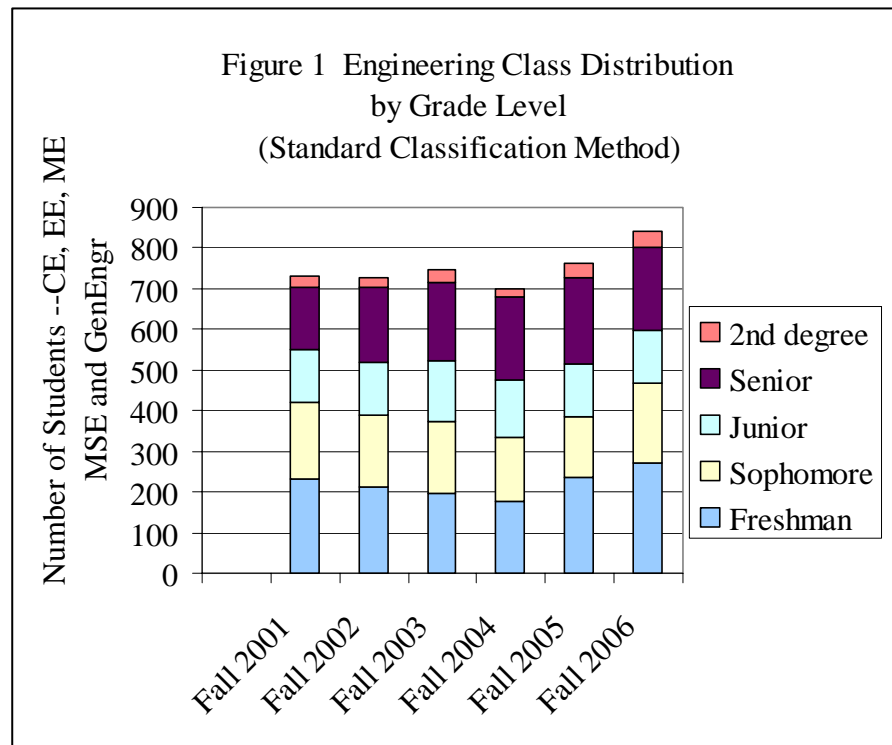
The aim was to develop more meaningful measures and indicators that would characterize student persistence and academic progress for ALL engineering students at Boise State University. The goals for the new model are indicated in Table 2.

Table 2: Standard and New Measurement Methods

Standard Reporting Methods	New Analysis Methods
Retention is routinely reported only for first-time, full-time freshman	Year-to-year retention is tracked for students of all levels
Retention is defined as whether the student is enrolled at the university the next fall	Engineering retention is defined as whether the student is enrolled the next fall AND still declares an engineering major
Transfer students are not included in any analyses	All students, including transfer students are included
Students are classified freshman through senior according to academic credits	Students are classified according to academic progress through the engineering curriculum

As the Hewlett Foundation grant focused on undergraduate students in engineering majors, the population studied was undergraduates majoring in civil engineering, electrical engineering, materials science and engineering, and mechanical engineering. Engineering students who had not yet selected a specific major were also included.

The first challenge was to devise a system to track student progress through the engineering program. The university classification system utilizes the standard four year, credit-based categorization of freshman, sophomore, junior, senior. The engineering student population sorted according to the standard credit-based classification system for the university 10-day report is shown in Figure 1.



The artificiality of compressing all the students into a four-category classification creates a top-heavy preponderance of seniors. Boise State is a metropolitan university where only 61% of students attend “full-time” (defined as at least 12 credits, which is less than the 15-18 credit load

required for engineering majors) and most students are employed. Additionally, the majority of students intending to major in engineering arrive unprepared for calculus. Therefore it is typical for many students to require more than four years to progress through the engineering curriculum. At Boise State University, a student like Stefano might acquire a sophomore or even junior level of credits in electives and core courses before qualifying to take calculus, considered a freshman level course in engineering, or even precalculus, considered a pre-freshman level course. Classifying such a student as a sophomore or junior would not correctly reflect progress in the engineering curriculum.

To classify students based on progress through the engineering curriculum, the team devised and applied an academic progress sieve to the PeopleSoft data base to sort the students. The team tried several designs and found that a top-down system that first tested the population for senior level course work, then the remainder for junior level courses, and so on, worked most effectively. Figure 2, which is divided over two pages, shows the algorithm to sort students based on their progress in the civil, electrical, materials and mechanical engineering curricula. The process begins by selecting all students who are enrolled as engineering majors on the 10th day of classes. Supplemental information on their gender, age, ethnicity, and financial aid status is then added to the file. For each student, all prior and current course enrollments and completions are then gathered, including any transfer courses for which students have received credit. After selecting the relevant courses, the sorting sieve is applied to obtain the student's status for that term.

Figure 2 Boise State Engineering Sieve for Class Categories

➤ First, consider all students. IF any of these tests is satisfied:

Completed (Any 2) (Mechanical)	Completed (Any 2) (Materials Science)	Completed (Any 2) (Civil)	Completed (Any 2) (Electrical)
Heat Transfer	MSE Laboratory	Engr. Properties of Construction Materials	Signals & Systems
Applied Mechanics of Materials	Mech. Behavior of Materials	Transportation Engr. Fundamentals	System Modeling and Control
Kinematics and Machine Dynamics	Thermodynamics of Materials	Reinforced Concrete Design	Microelectronic Circuits
			Microprocessors

OR IF any of these tests is satisfied

Enrolled (Any 2)	Enrolled (Any 2)	Enrolled	Enrolled
Mechanical Engineering Lab	Phase Transformation and Kinetics	Engineering Practice	Senior Design Project
Machine Design	Senior Project		
Thermal and Fluid Systems Design	Materials Analysis		

➤ THEN Classify as Senior. (Continue on next page)

Figure 2 Boise State Sieve for Class Categories (continued)

➤ Next, consider the remaining students. IF any of these tests is satisfied:

Completed (Any)	Enrolled (Any 2)	Enrolled (Either)	Enrolled (Any 2)	Enrolled (Any 2)
Differential Equations	Thermodynamics	Bonding, Crystallography & Crystal Defects	Environmental Engineering	System Modeling and Control
Calculus III	Engr. Mechanics of Materials	Electrical Properties of Materials	Structures	Microprocessors
Circuit Analysis & Design	Fluid Mechanics		Engineering Properties of Solids	Electromagnetic Theory

➤ THEN Classify as Junior

➤ Next consider the remaining students. IF any of these tests is satisfied:

Completed	Enrolled	Enrolled (Either)	Enrolled (Either)
Calculus II	Intro to Materials Science and Engineering	Engineering Statics	Calculus III
	Physics II with Calculus	Electrical and Electronic Circuits	Differential Equations

➤ THEN Classify as Sophomore

➤ Next consider the remaining students. IF any of these tests is satisfied:

Completed (Any)	Enrolled (Either)	Enrolled (Any)
Analytic Trigonometry	Calculus I	Intro to Engineering
Precalculus	Calculus II	Intro to Civil Engineering
Calculus I		Engineering Graphics

➤ THEN Classify as Freshman

➤ Next consider the remaining students. IF any of these tests is satisfied:

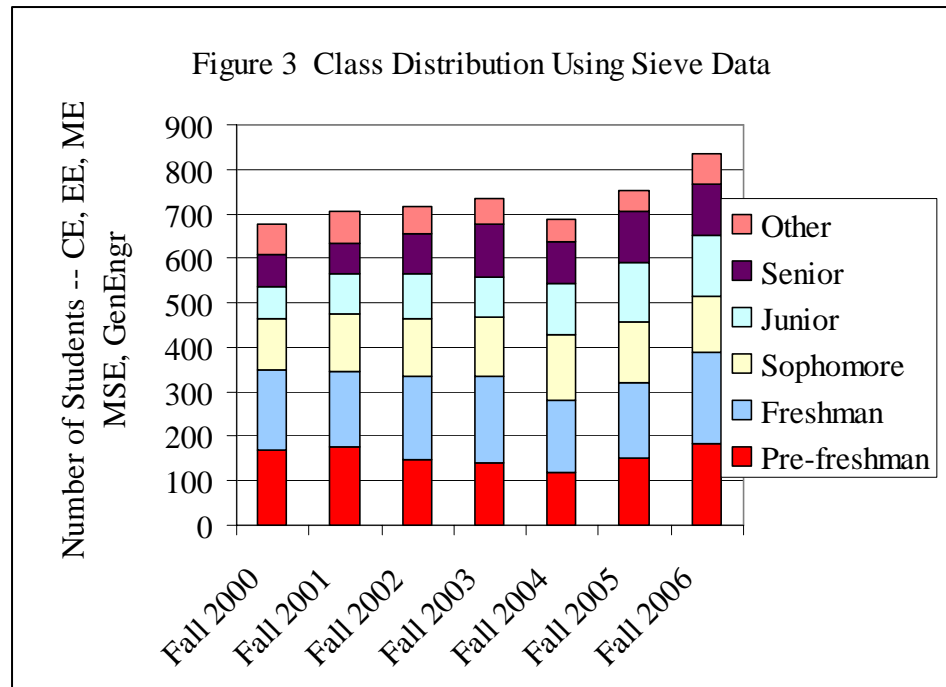
Enrolled (Any)
Elementary Algebra
Intermediate Algebra
College Algebra
Analytic Trigonometry
Precalculus

➤ THEN Classify as Pre-freshman

➤ ELSE Classify as Other and check each record

Figure 3 classifies students according to the sorting sieve. The distribution created indicates a trend toward more balanced proportions in the sophomore through senior levels, indicating steady progress through the curriculum.

The most striking trend that emerges is the large number of students who are classified as pre-freshman. This is not surprising because, as Figure 2 indicates, pre-freshman are students enrolled in any level of math below calculus. Even though Boise State University



has the highest admission standards among the state’s higher education institutions, there are no special admission requirements for engineering students. Any student with an interest in engineering (such as Jim, for example) may declare an engineering major from the time of admission, no matter what the level of math. The university requires a Math ACT of at least 29 or SAT of at least 650 to qualify for placement in Calculus I. *About 70% of students who successfully graduate with engineering degrees at Boise State University begin their first semester in a class below calculus level.*⁵

Figure 3 also shows that the proportion of students at a given level is smaller than the proportion of students at the earlier level, which is to be expected since a certain amount of attrition occurs at each level. The exception is the senior class, which reflects the fact that the final portion of a program is often spread out due to work and other factors.

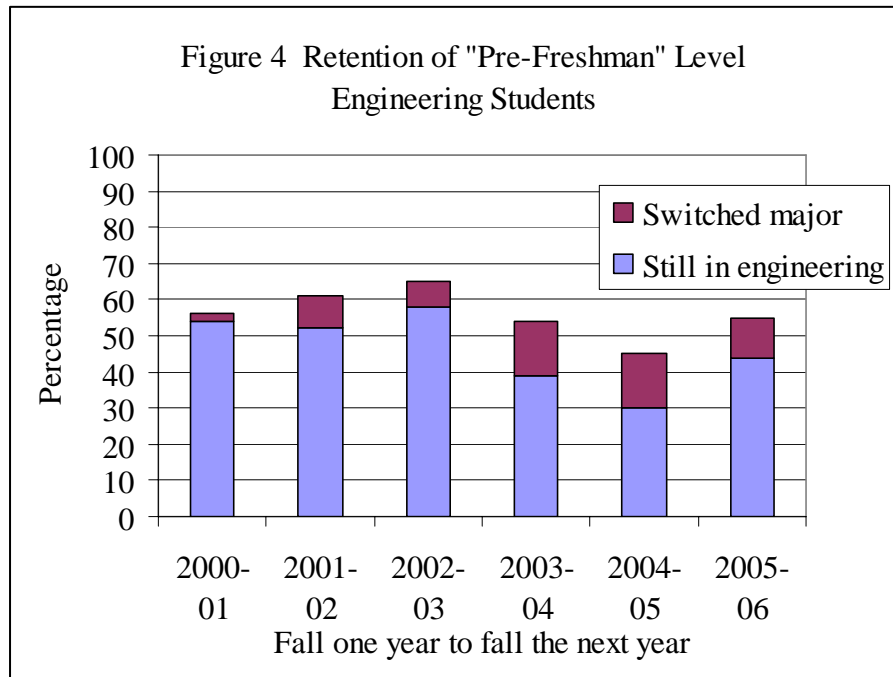
Putting the Sieve to Work

Now that the sieve has been established, queries can be run to sort students in order to answer numerous questions and create programmatic changes based on the answers.

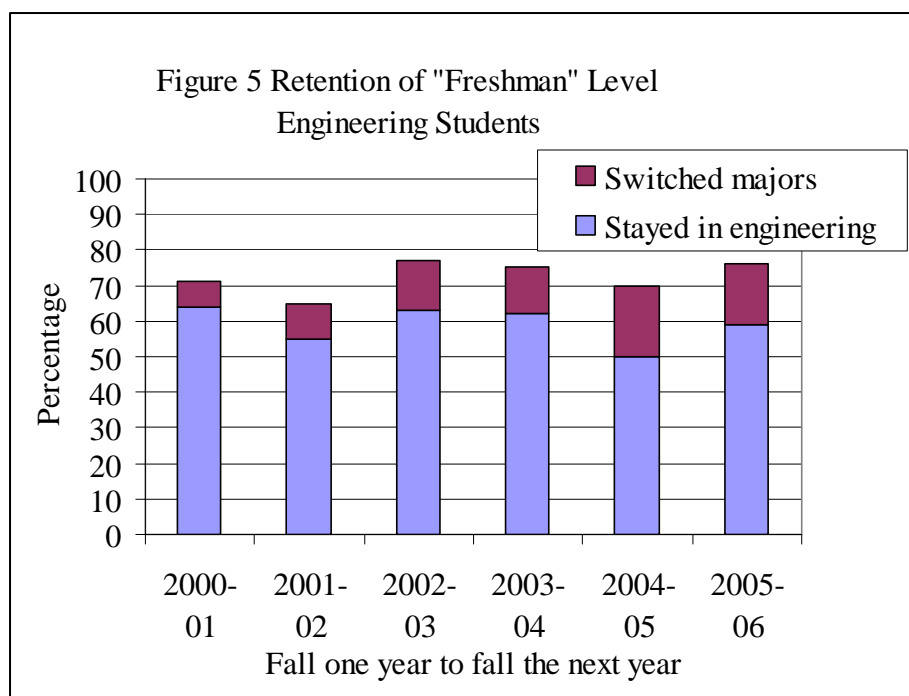
- 1) What is the year-to-year retention of students at each of the class levels, pre-freshman through senior?

Retention is defined as the condition where a student who was enrolled in a fall semester is still enrolled the next fall semester. First let’s examine the pre-freshman and freshman level students, shown in Figures 4 and 5. For example, the “2000-01” bar on Figure 4 shows that of the

engineering students who were pre-freshman level in fall 2000, 56% were still enrolled at the university in fall 2001. Additionally, the query sorted whether students were retained not only at the university but as engineering majors. In this case 54% of students were still engineering majors and 2% changed to another major. (The remaining 44% of students were no longer at the university.) Figure 5 shows that freshman level students achieve a higher retention rate than pre-freshman level students.



Note that the percentage of students changing to a major other than engineering increased from 2004 to 2005 and 2005 to 2006 for both pre-freshman and freshman. The likely reason is that in fall 2004 the university enabled students to log in online and easily change their majors. Previously, a student needed to purposefully go to the registrar's office and fill out an official form declaring a change of major.

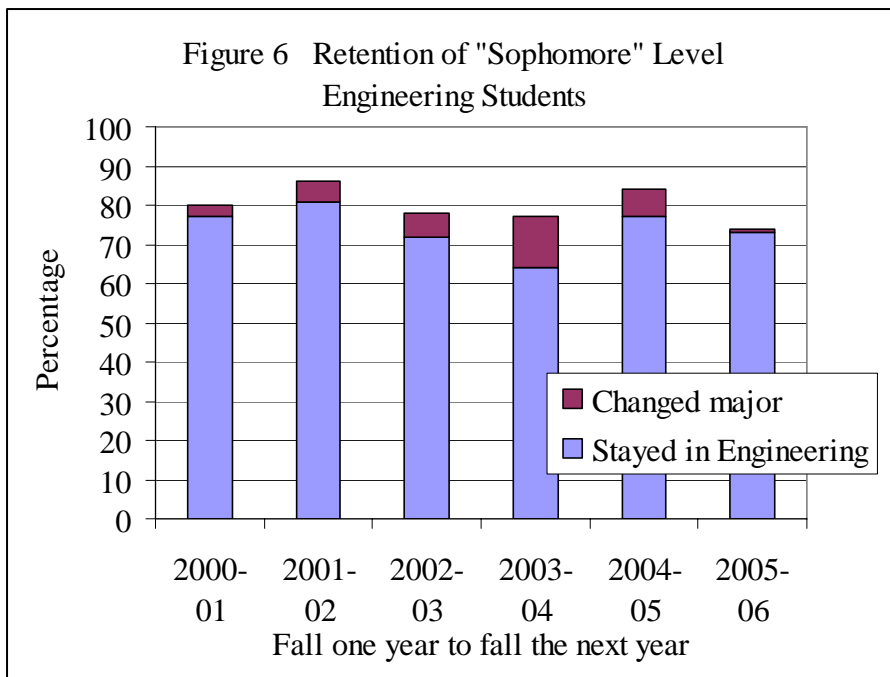


In a separate study not included in the scope of this paper, the institutional assessment office determined that high performance in early math classes was highly correlated with retention. And conversely, poor performance in math was correlated with the student leaving the university.⁵ This factor (performance in first math class) was found to be more significant than their original math placement level.

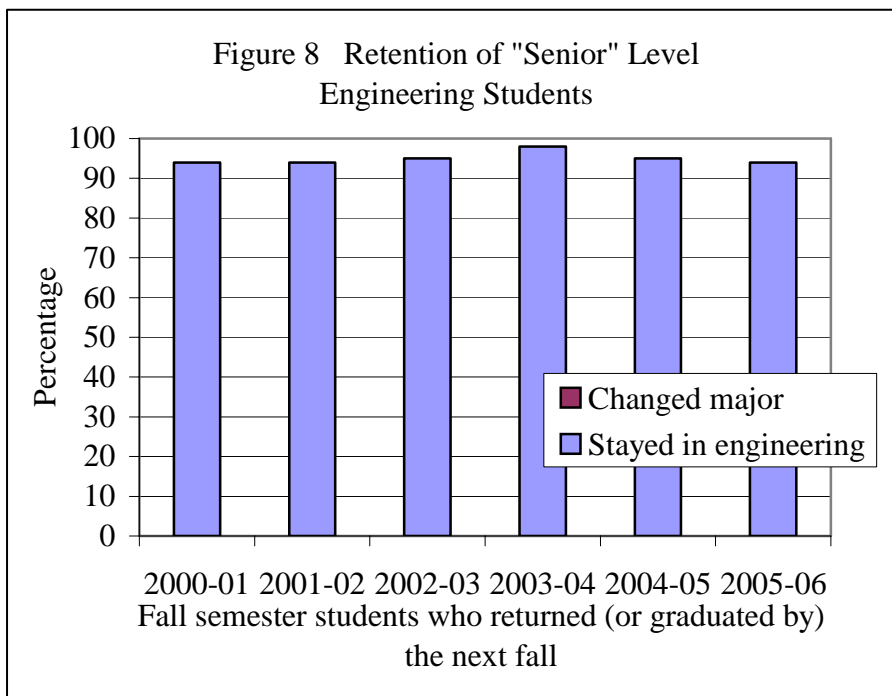
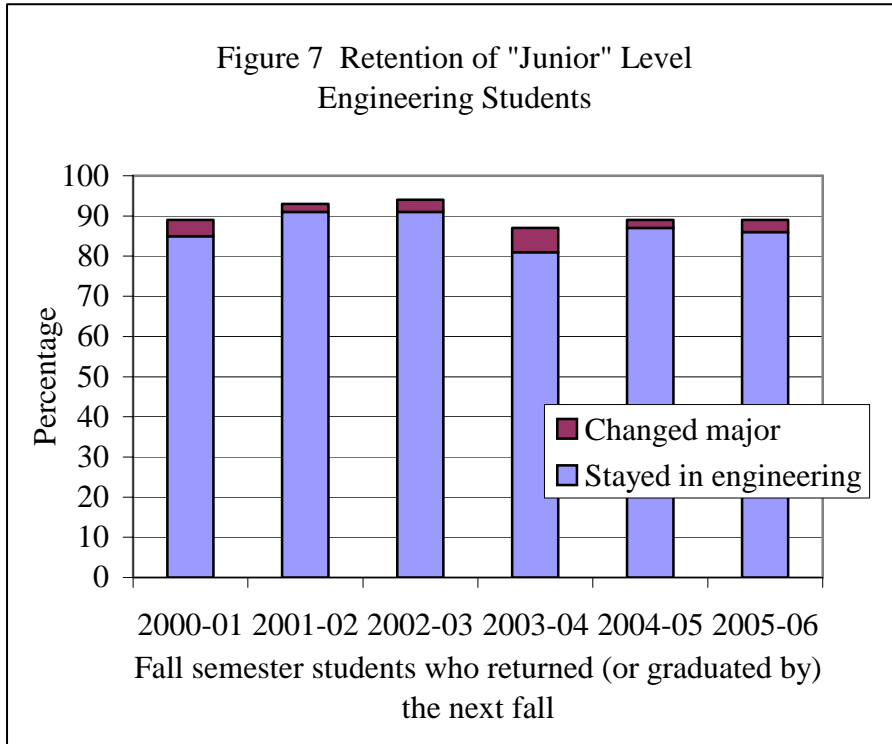
In an effort to boost student success in math, Boise State University instituted the following programs with significant input from this research team:

- In spring 2003, the College of Engineering began sponsoring supplemental instruction sessions for all students (not just engineering students) in precalculus through calculus II. However, there were no extra sessions offered for students below precalculus level due to the logistics of the high enrollment numbers in those classes.
- In 2004, the College of Engineering began offering Learning Communities for students at the pre-freshman and freshman levels. In Learning Communities, students are grouped together in multiple classes to foster connections, study groups and improved retention. Two Learning Communities were offered in academic year 2004-2005, five in 2005-2006, and eight in 2006-2007.
- In fall 2005, the College of Engineering began offering an Introductory Engineering class for precalculus level students. A major emphasis of this class was math preparation utilizing the McGraw-Hill math education software ALEKS (Assessment and LEarning in Knowledge Spaces).⁶
- In fall 2006, the College of Engineering partnered with the math department to identify students who were struggling in the first five weeks of the precalculus class (a very accelerated 5-credit class covering college algebra and trigonometry) and to advise the students to move into a specially created slower paced section that focused solely on college algebra.

To complete the retention picture, Figures 6, 7 and 8 show the retention for students enrolled in sophomore, junior and senior level coursework. As one would expect, retention, both within the university and within engineering, steadily increases for each class. However, the team found it



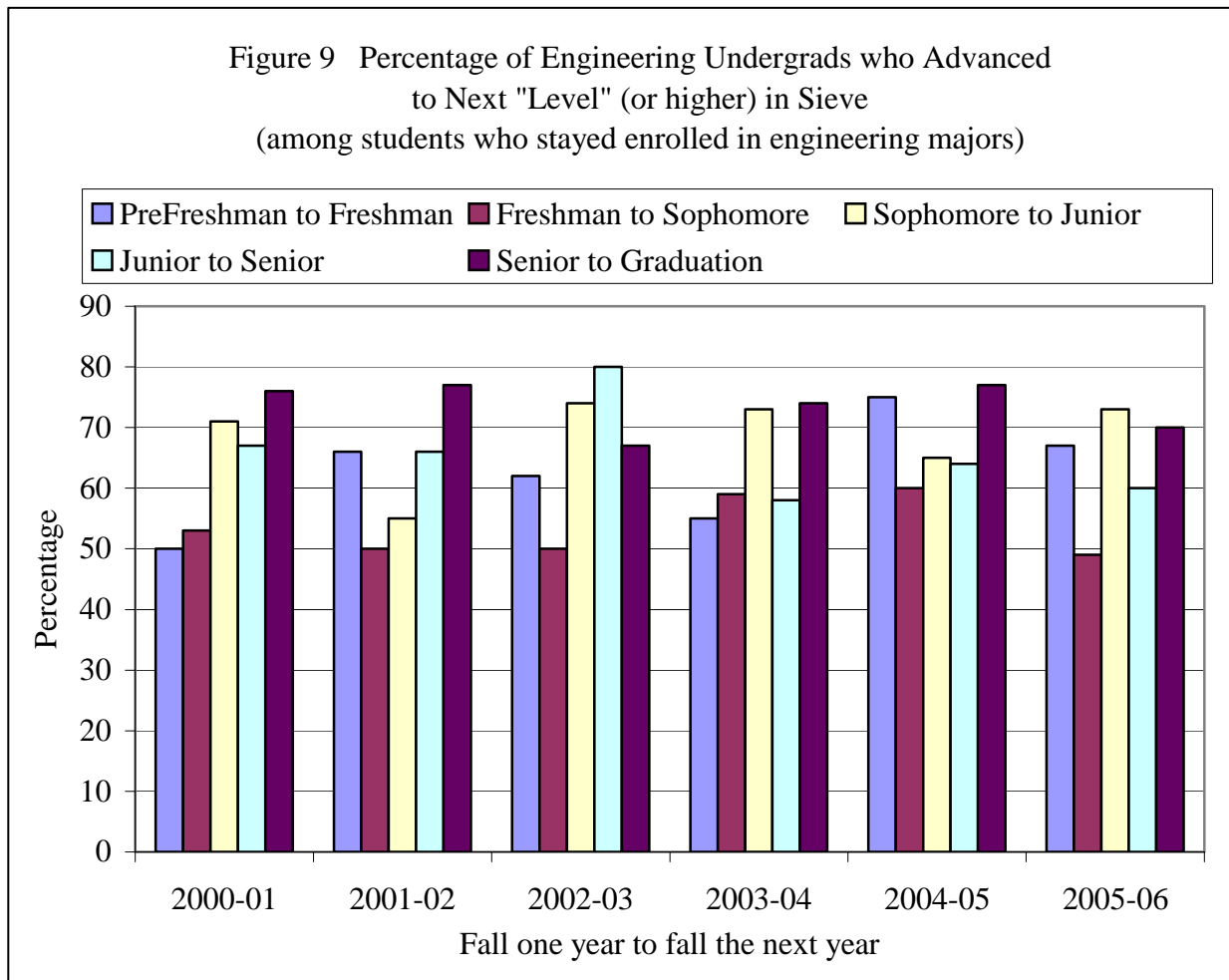
surprising that attrition in the higher levels was still significant. This supports the premise that attrition can be attributed to a large number of factors, not just academic performance, since it's rare for juniors or seniors to "flunk out" of a program.



2) Are students making progress from one level to the next?

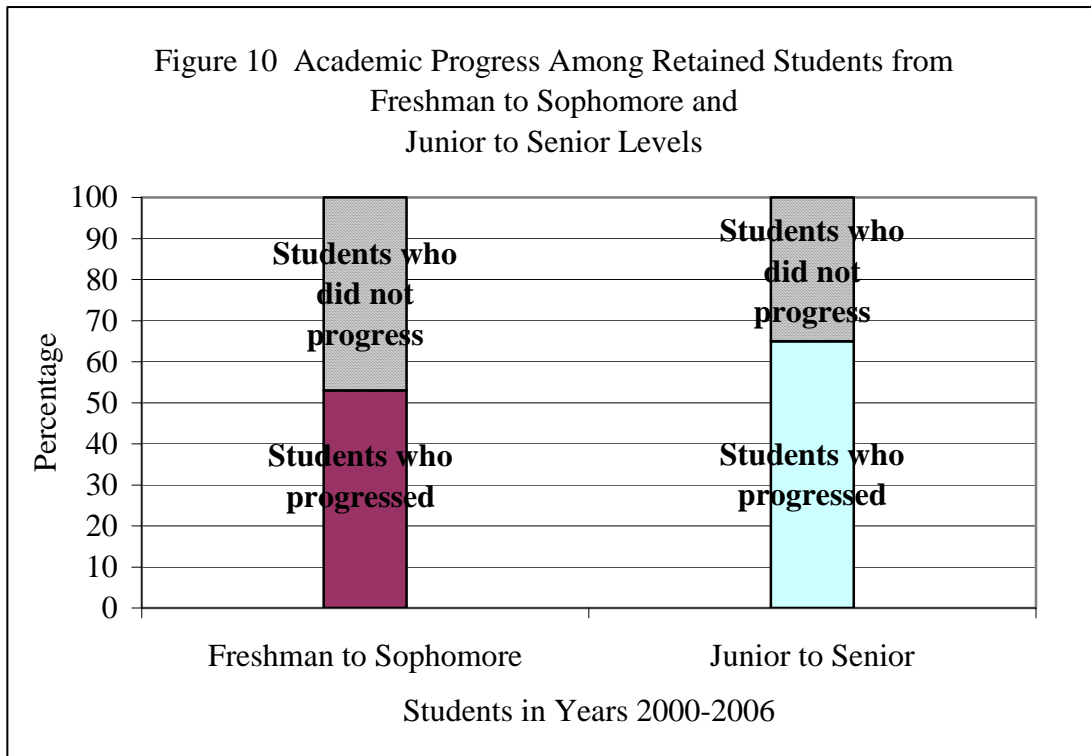
The primary reason the sieve was created was to gauge progress of students from one level to the next. Due to the factors already identified – students entering college lacking advanced preparation in math and students balancing work, family and studies – most of the students in

Boise State's College of Engineering require more than eight semesters to complete the engineering curricula. Figure 9 shows the advancement of the students to the next level among those who were retained and stayed enrolled as declared engineering majors. For example, from fall 2000 to fall 2001, the graph shows that 50% of pre-freshman who were retained advanced to freshman level or higher courses the next year. The other 50% still had pre-freshman level course requirements to fulfill. Among seniors, generally 25-30% of students require more than one year to complete the senior curriculum.



The progress from freshman to sophomore level and from junior to senior coursework is where the bottleneck occurs for many students. Sluggish progress through the calculus series slows down students progressing from freshman to sophomore level, and fundamental engineering classes present a hefty course load for junior level students. "Progress" is defined as completing the freshman or junior level of course work defined in the Figure 2 sieve. Figure 10 summarizes the average number of retained students who progressed yearly from the freshman to sophomore level (53%) and junior to senior level (65%) over the past six years. Note that these students are taking appropriate classes, they simply have not completed all their course work at the freshman or junior levels, respectively. Recognizing this situation helps faculty offer appropriate

expectations and advising. Looking at Figure 10, it is easy to see how a student might take six years or more to earn an engineering degree.



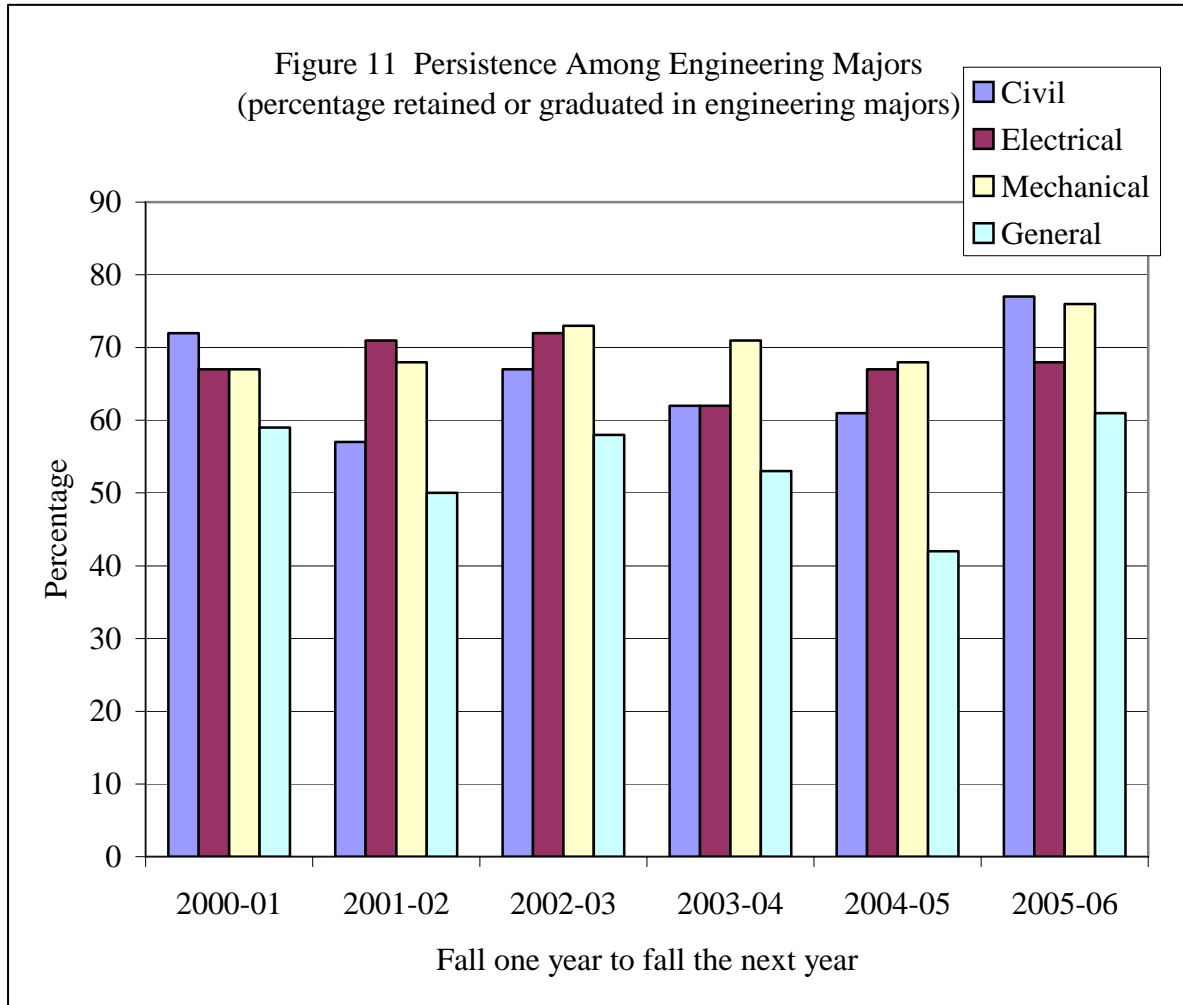
Need for employment has been cited by many Boise State students as the reason for their slower progress through the curriculum. For that reason, the university has increased its efforts to provide scholarships and on-campus employment. A program, also sponsored by the Hewlett Foundation grant, was begun in 2004 to place lower division students (freshmen and sophomores) in internships at area companies and university research labs. In academic year 2005-06, retention was 97% among the 32 lower division participants.⁷

3) Does retention vary among students in each of the four engineering departments?

As each of the four engineering departments has different curricula, the team questioned whether retention varies among departments. Figure 11 shows the overall retention (all levels) from year to year for each department. Only civil, electrical, mechanical and general (students who have declared an intention to major in engineering but have not yet picked a specific department) are included. As the complete materials science undergraduate curriculum was offered for the first time in 2005, there is not yet enough data for analysis.

In this case, retention is again defined as staying enrolled at the university as an engineering major. The patterns are fairly consistent year to year. Most noticeable is that students who declare a general engineering major are generally retained at a lower rate. Most of these students are probably pre-freshman level students, whose retention is low. The College of Engineering

has placed an increased emphasis on advising by assigning senior faculty to advise students at the orientation sessions for incoming freshman. The university requires advising only for incoming degree-seeking freshman and transfer students at their orientation session. Even though academic advising is not required for any level of part-time student and for all continuing students, the College of Engineering is proactive about contacting all students and encouraging them to meet with an engineering faculty advisor. The associate dean personally meets with students who declare general engineering to help them choose a specific engineering major so that they can begin forming connections with faculty and students in that department.



Another question the team considered was whether overall retention varies with gender or ethnicity. No significant difference was seen for either. The sieve is a flexible tool that enables the student population to be filtered in dozens of ways to answer questions about factors affecting student success. A particular engineering department could look at its own retention by level and academic progress. Or students can be filtered as to their retention or progress based on specific admissions factors or indicators, or transfer status, or whether they are employed on campus, or whether they started their first semester at a particular math level.

Conclusion

Boise State University has made it a priority to increase retention among first-time, full-time freshman. Math support programs, an increased emphasis on advising, a new engineering class especially for precalculus level students, and lower division student internships are some programmatic changes that have been implemented as a result of this research. The team is encouraged that these program changes may be contributing to the recent upward movement in pre-freshman and freshman retention, as shown in Figures 4 and 5, and overall retention, as shown in Figure 11.

The sieve is a sorting method that can be adapted to almost any university data base to help understand student road blocks to success. An engineering college can customize the sorting process based on its own curriculum. New assessment tools are timely in the current context where U.S. politicians, citizens and business leaders recognize the vital role higher education plays in U.S. economic vitality and international competitiveness. In September 2006, U.S. Secretary of Education Margaret Spellings announced an action plan for improving accessibility, affordability and accountability of higher education.

“If you want to buy a new car you go online and compare a full range of models, makes, and pricing options,” said Secretary Spellings at a National Press Club speech in September 2006.² “And when you’re done you’ll know everything from how well each car holds its value down to wheel size and number of cup-holders. The same transparency and ease should be the case when students and families shop for colleges.” Specifying and measuring the academic equivalents of cup-holders and value are subjects sure to engender lively debate in academe. The assessment methods described in this paper will add one voice in the discussion.

Acknowledgements

The authors gratefully acknowledge the support of the William and Flora Hewlett Foundation’s Engineering Schools of the West Initiative.

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