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A Novel Tool to Visualize Student Flow Through the Curriculum

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A Novel Tool to Visualize Student Flow Through the Curriculum

Abstract

Engineering enrollment at Baylor University increased by more than 110% from fall 2001 to fall 2010. The increase taxed both our faculty and facilities and prompted the need for enrollment management measures. Risk-factor and logistic regression analyses led to the implementation of a B or better requirement for the freshmen engineering course sequence in fall 2011. Effective with fall 2013, incoming freshmen engineering students were required to meet minimum SAT/ACT scores to declare Pre-Engineering as their major. These students were required to earn semester grades of B or better in the two-semester freshmen engineering course sequence to qualify to declare a degree-granting engineering major. These policies were coupled with aggressive advising for at-risk students with the intent to improve retention to graduation from our university regardless of their final major. An enrollment model for evaluation of alternative standards for admission was developed in 2014 for enrollment management at a sustainable level. The development of these measures was presented at previous FYEE conferences and resulted in improved 6-year graduation rates among our incoming engineering cohorts in subsequent years.

Additional data mining of enrollment databases used in the development of enrollment management measures allowed further slicing of engineering enrollment into smaller cohorts of interest. Example sub-populations of interest include underrepresented minority, women, military veterans, and first-generation students. Further, students who lived in the Engineering and Computer Science Living and Learning Center and, later, Residential College were compared to students who lived in other campus housing to identify retention issues related to their housing location. This amount of data became overwhelming rather quickly. We applied the use of a graphical application, e!Sankey pro (ifu Hamburg GmbH) that is more commonly used by engineers to map energy, fluid, material, or traffic flow in a variety of industries. The movement of students through the engineering curricula was treated as a flow problem. Arrows representing flow of students are sized relative to the original numbers of students in a particular cohort and give the viewer a quick sense of where these students go, whether it is graduation with an engineering degree, retention at our university in another major, or departure from the university. This graphical method applied to student flow allows for the rapid understanding of a great deal of data. It has proved a valuable tool for the assessment of retention and enrollment management measures year by year.

Introduction

An increase in engineering enrollment at Baylor University (BU) by more than 110% from fall 2001 to fall 2010 taxed both our faculty and our facilities and prompted the need for enrollment management. Risk-factor and logistic regression analyses led to the implementation of a B or better requirement for the freshmen engineering course sequence in fall 2011. Effective with fall 2013, incoming freshmen engineering students were required to meet minimum SAT/ACT scores to declare Pre-Engineering as their major. These students were required to earn semester grades of B or better in the two-semester freshmen engineering course sequence to qualify to declare a degree-granting engineering major. These policies were coupled with aggressive

advising for at-risk students with the intent to improve retention to graduation from our university regardless of their final major. An enrollment model for evaluation of alternative standards for admission was developed in 2014 for enrollment management at a sustainable level. The development of these measures was presented at previous FYEE conferences [1-4] and resulted in improved 6-year graduation rates among our incoming engineering cohorts in subsequent years. One of the tools that we used extensively through this process was the use Sankey plots to model student flow through the engineering curricula. Sankey plots were originally developed by Matthew Sankey in 1898 for diagramming energy efficiency of a steam engine [5] and have been used in science and engineering to model a flows. The second author of this work was familiar with the use of Sankey plots in HVAC research to illustrate both air flow rates and energy usage. Sankey plots are notable because arrows that indicate flows are sized to provide a sense of the relative flow rates throughout the system. While we are not the only researchers to apply the use of Sankey plots to model student flow to retention [6], we developed a visual tool that provides the viewer with a method to easily understand a large amount of interrelated data.

Visualization of a Student Cohort's Flow through Engineering Curricula

Following the progress of a student cohort through a curriculum is a non-trivial exercise because of the number of factors at play and the number of possible pathways that a student may travel on the way to graduation with an engineering degree. Some questions we addressed when studying persistence in engineering included:

- Does the first mathematics course (PreCalculus, Calculus 1, Calculus 2, or Calculus 3) taken our university indicate possible retention issues?
- Does retention to graduation differ between students who lived in our Engineering & Computer Science Living-Learning Community (ECS-LLC) vs. those who do not?
- Are women retained to graduation at the same rates as men?
- Are minority students retained to graduation at the same rates as Caucasian students?
- Do students who change their major from engineering remain at our university or do they drop out?
- Do suspended students return to our university and earn their engineering degree?

Definition of Cohort

In developing our visualization tool, we first defined a cohort for a particular year:

- Enrolled at BU as incoming freshmen in the fall semester.
- Declared an engineering major.
- Enrolled in our first-semester freshman engineering course, EGR 1301 – Introduction to Engineering.

Explanation of Sankey Plot

The definition of a cohort population allows us to drill down through the population to visualize the effects of different factors on retention to graduation in engineering. All Sankey plots were generated using e!Sankey pro v3.2 (ifu Hamburg GmbH). Figure 1 is an example of a Sankey plot of the fall 2003 cohort. In our plots, the first and largest arrow represents the size of the cohort in the fall semester of the freshman year. All other arrows are sized relative to that arrow

and provide a visual sense of the size of the population that traveled down a particular path. The distinctive features of each Sankey plot are as follows:

- The starting point of the flow diagram is the left-most and largest of the horizontal yellow arrows, which contains 100% of the cohort. The heading "Incoming Freshmen Engineering Students" is just to the left of that arrow.
- Enrollments at the beginning of each following fall semester are indicated by each subsequent horizontal yellow arrow.
- Each horizontal yellow arrow is labeled with the year, the number of students represented by that arrow, the percentage of the initial cohort, and the average SAT of those students.
- All other arrows indicate either fall-to-fall flow out of engineering majors or flow back into engineering majors. These arrows are labeled with the number of students, the percentage of the initial cohort, and the average SAT of those students. ACT scores are converted to SAT using Concordance Tables for that particular year (www.act.org).
- The blue arrows, labeled "COM Out," represent students who remained at our university but who changed their major from engineering to another major.
- The dark gold arrows, labeled "COM In," complete the loop with the blue arrows and represent students from the initial cohort who changed their major from engineering to another major but then changed back to engineering.
- The red arrows, labeled "Left," represent students who left the university either because they dropped out, transferred to another school, or were placed on academic suspension.
- The green arrows, labeled "Return," complete the loop with the red arrows and represent students who left our university for at least one semester and then returned as an engineering major.
- The purple arrows, labeled "Graduate," represent students who graduated from our university with an engineering degree.

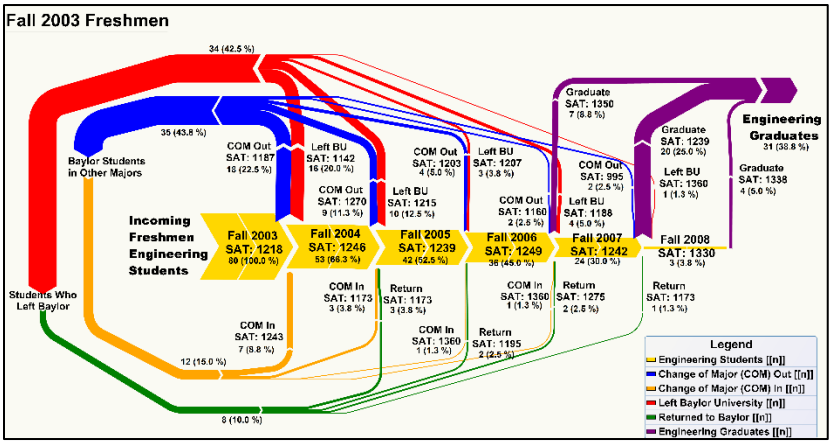

Figure 1 – Fall 2003 freshmen engineering cohort.

Visualization of the effect of a single event

Incoming freshmen at BU must reside on campus unless they live at home with their parents. Prior to 2004 freshmen engineering students were housed with the general student population. In fall 2004, our first ECS-LLC opened. For the first time, students were housed with other students in related majors and with upperclassmen who could provide unofficial mentoring and help with

homework. LLC programming, such as tutoring and community-building events, were offered to help increase retention to graduation. There are startling differences between the fall 2003 cohort (Figure 1) and the fall 2004 cohort (Figure 2). A similar percentage of students, 43.8% in 2003 and 42.5% in 2004 cohorts, changed their majors from engineering to another major, but there was an increase from 15.0% in 2003 to 21.8% who changed their majors back to engineering. There was a drastic decrease from 42.5% in 2003 to 27.6% in 2004 who left the university, but a similar percentage returned to the university in each cohort. Along with the decrease in loss of students from our university, the 6-yr graduation rate jumped from 38.8% in the 2003 cohort to 60.9% in the 2004 cohort. While there are many factors that determine student persistence in engineering majors, the opening of the ECS-LLC played a role in the increased retention to graduation of our 2004 ECS cohort.

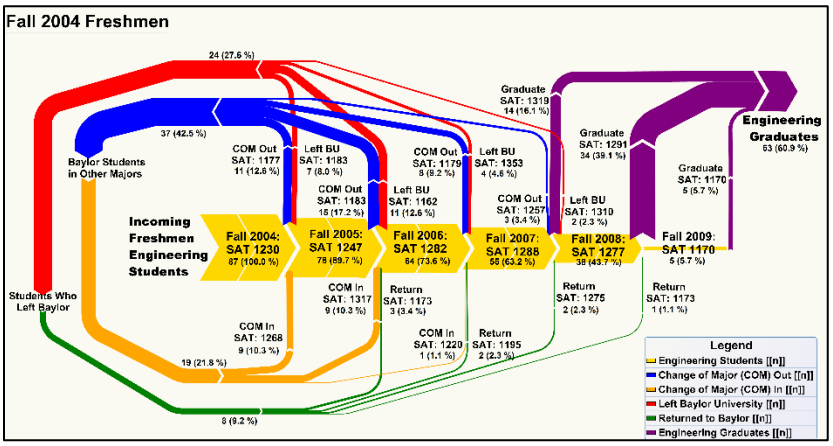

Figure 2 – Fall 2004 freshmen engineering cohort.

Combination of multiple cohorts for study of additional factors

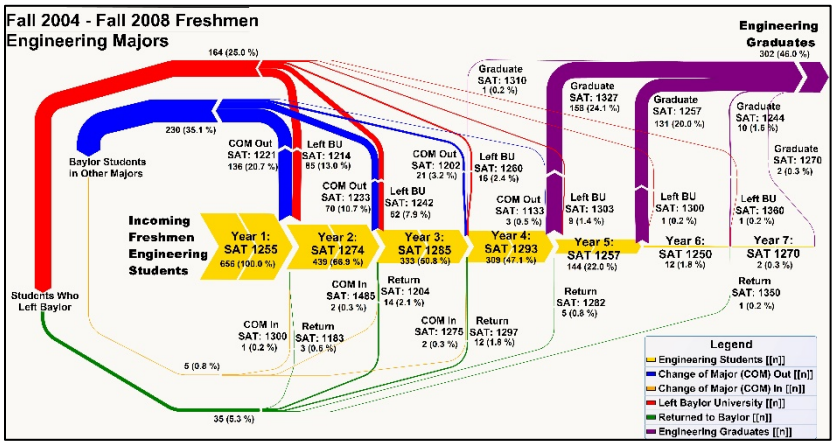

Figure 3 – Five years of freshmen cohorts combined for further analysis.

The combination of cohorts from multiple academic years allows us to increase the population of interest that allows us to study other factors that may affect subpopulations within cohorts. In Figure 3, we combined cohorts from five successive years. One analysis using this population underwent analysis of 6-year graduation rates, not presented in this paper, by stratification based on SAT/ACT scores [3] as we developed our initial enrollment management proposal [3]. Figure 4 illustrates how we drilled down into the data to identify possible issues related to the first math

course students attempted at BU. Students who enrolled in PreCalc (Figure 4a) made up 32.3% (212) of the 656 students in the combined cohort with a 22.6% 6-year engineering graduation rate (6yrEGR) and supported the need to freshmen engineering students to be calculus-ready. Students enrolling in Calc 1 (Fig 4b) were 46.5% (305) of the combined cohort with a 62.6% 6yrEGR. Students in Calc 2 (Fig 4c) were 13.4% (88) of the cohort with a 73.3% 6yrEGR. Students in Calc 3 (Fig 4d) were 6.3% (41) of the cohort with a 65.9% 6yrEGR. Surprisingly, Calc2 students displayed the highest 6yrEGR. Although 27.3% of this group changed their major out of engineering, 18.2% changed their major back to engineering. One finding of concern was that almost 25% of the Calc3 students left our university without earning a degree. Further data analysis of Calc3 students revealed that an alarming 25% of this group of students considered to be highly prepared for college calculus earned a D or F in their first math course. These findings led our advisors to aggressively advise students who were not calculus ready to consider either declaring a different major or take PreCalc in the summer before enrollment at Baylor and to advise students with AP Calculus credit to consider forfeiting one semester of AP Calculus credit and thus ease their transition to college-level studies.

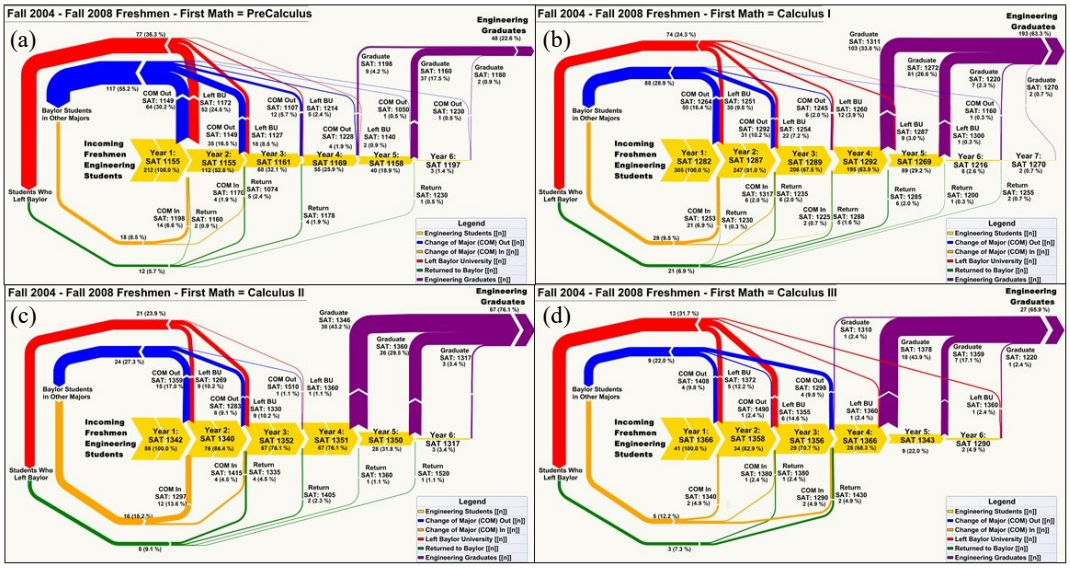

Figure 4 – First math course at BU. The combined five years of freshmen cohorts from Figure 3 were further sliced, based on the first math course attempted at Baylor University: (a) PreCalculus, (b) Calculus 1, (c) Calculus 2, and (d) Calculus 3.

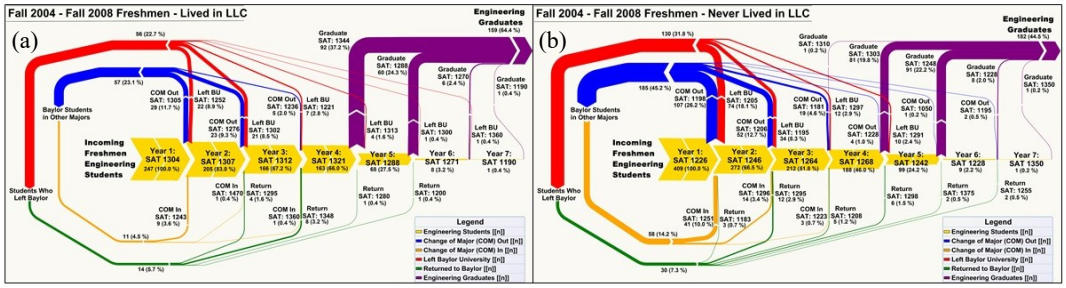

Figure 5 – On-campus housing. The combined five years of freshmen cohorts from Figure 3 were further divided between (a) those who at some point lived in the ECS-LLC and (b) those who never lived in the ECS-LLC.

Figure 5 illustrates the effect of the ECS-LLC. Those students who lived in the ECS-LLC at some point in their academic career at Baylor were 37.7% (247) of the combined cohort with a 63.7% 6yrEGR compared to the 44.3% 6rEGR of those who never lived in the ECS-LLC. In the ECS-LLC group, 22.7% of the students left the university and 23.1% changed their major, but in the other group, those numbers were 31.8% and 45.2% respectively.

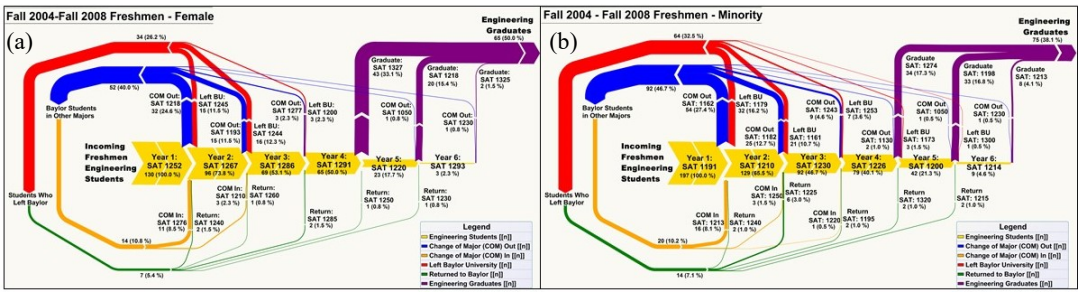

Figure 6 – Underrepresented groups and retention to graduation. The combined five years of freshmen cohorts from Figure 3 were further sliced into (a) female students and (b) minority students.

In figure 6, we split out female and minority students. The 6yrEGR were 50.0% in women and 38.1% in minorities. Further mining of the data led us to discover that 75% of minority students never lived in the ECS-LLC. This analysis supported the development of a Learning Resource Center [4] to provide programming and tutors for non-ECS-LLC students.

Conclusion

While there is no statistical analysis or claim of causality with this type of analysis, visual presentation of data in this manner allows for quick comprehension of a large amount of complex data. The use of Sankey plots to drill down into a cohort to identify the possible effect of different factors on retention to graduation in engineering has become a powerful tool.

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