The Introductory Sequence for Chemical Engineering Students and Retention at Tri-State University

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Abstract

The introductory sequence for first-year chemical engineering students at Tri-State University consists of a series of two courses. These courses are designed to introduce the student to their chosen field of study. Computer packages such as MSWord and Excel, which are used throughout the curriculum, are utilized extensively. Most importantly, the student is introduced to the design process used to solve open-ended problems through a variety of "hands-on" and cooperative learning activities.

Introduction to Engineering is the first course in the sequence and is common for all first-year engineers, while *Introduction to Chemical Engineering*, the second course in this series, is directed toward students in this discipline. This paper presents a synopsis of these two courses, focusing on the latter. It specifically documents the content of these two courses and the positive impact these two courses have had on subsequent retention of students in the chemical engineering program.

I. Introduction

Tri-State University (TSU) is a private, undergraduate institution with a rich tradition of providing an affordable, "hands-on" engineering education. Located in Angola, Indiana, TSU is approximately 45 miles northeast of Ft. Wayne and 60 miles west of Toledo, Ohio. From its start in the late 1800's as a normal school, TSU has grown into a regional educational leader for the 21st century specializing in engineering, business, and education. Of the more than 1200 students on campus, roughly one-half are enrolled in the School of Engineering and Science (SOES).

Begun in 1909, the Chemical Engineering (ChE) Department at TSU has remained a small undergraduate program with a focus on career-oriented higher education. Departmental enrollment currently stands at very nearly 60 students, having dipped as low as 37 in the late 1980s. With as few as 20-25 students entering the program each year, retention is a critical issue for the viability of the program in a primarily "tuition-driven" budgeting environment. To maximize contact with incoming students, the department took advantage of a recent (1998/1999) conversion from a quarter-based academic calendar to one based on semesters to evaluate and revise our entire curriculum.

The introductory course sequence for first-year (frosh) chemical engineers at Tri-State University consists of *Introduction to Engineering* and *Introduction to Chemical Engineering*.

Introduction to Engineering is taught fall semester and is common to all engineering frosh, while *Introduction to Chemical Engineering* is taught spring semester and is directed toward students keenly interested in this discipline. These courses are designed to teach basic engineering skills common to all engineering curricula and generate student excitement about their chosen field of study. This paper presents an outline of these two courses and discusses their dramatic impact on student retention in the chemical engineering program.

II. Introduction to Engineering (first semester)

Introduction to Engineering (GE101) is the first course in the sequence and is required for all engineering frosh. Its purpose is to promote academic success, to make the college experience more relevant to career goals, and to help students obtain as much assistance as possible from the university while working toward their engineering degrees. The course emphasizes community building, academic goals, effective learning methods, University orientation, and personal and professional development. An important aspect of this class is exposure to each of the major engineering disciplines.

GE101 is designed to help students reach their potential, not load them down with additional "busywork" while they may be struggling with the likes of calculus and chemistry. The text, *Studying Engineering: A Road Map to a Rewarding Career*[1], attempts to motivate prospective engineers by explaining the undergraduate engineering educational system and providing many personal anecdotes. Most classes are designed to be one-half lecture and one-half group-based learning activity, with each class meeting requiring some preparatory work outside of class. Typically, preparatory work includes reading and/or writing assignments, but does include things as varied as a university fact-finding scavenger hunt. Class activities are designed to develop the tools and techniques needed to excel in a student's chosen academic program.

The culmination of the course is a presentation on the student's intended major. This month-long activity begins with interviews of an upperclassman, a faculty member, and a working engineer in the major of interest. Each student writes a paper summarizing his or her findings and outlining a plan of study. Students then work in groups of three with like interests (major and job function) to develop an informational presentation which is given to their entire class during the final examination period.

At the completion of the course, the student is to be able to:

a) feel a part of the university community by knowing at least one engineering faculty member, by knowing their classmates, and by attending a professional society meeting on campus,
b) describe the various fields of engineering, the engineering design process, professional registration, and the National Society of Professional Engineers' Code of Ethics,
c) effectively utilize university resources, such as academic advising, tutoring, the registrar, computing facilities, the library, career services, and the fitness and wellness center,
d) discuss what they want from their education and how they are in control of their own success.

Success in achieving these objectives is discerned from a student's performance on both the pre-lecture preparatory assignments and the in-class group-based learning activities. Letter grades are assigned based on student attendance, in-class participation, and performance on required assignments.

GE101 is taught by a cohort of six engineering faculty, with each teaching a section of 25-30 students. Each of the four engineering programs at TSU (Chemical, Civil, Electrical, and Mechanical) provides at least one faculty member for this cohort. In order to expose students to all of the engineering disciplines (and hopefully confirm interest in their chosen field), incoming students are dispersed as randomly by discipline as possible between the various sections.

III. Introduction to Chemical Engineering (second semester)

Introduction to Chemical Engineering (ChE111) is the second in this series of frosh engineering classes. It focuses solely on defining this discipline and, more importantly, on getting students excited about the rigorous educational path upon which they are about to embark. It is typically taken by first year students and occasionally transfer students who are classified as sophomores. It is a required one-hour credit course, which meets two hours a week to facilitate interactive learning exercises and field trips. Enrollment is usually on the order of 15-25 students per semester.

A perceived shortcoming of the curriculum under the quarters system was that students were not integrated into the chemical engineering core curriculum until they were sophomores. Requiring all ChE frosh to take *Introduction to Chemical Engineering* as second semester students immerses students into the program beginning in their first year of study instead of their second.

At the completion of the course, the student is to be able to:
a) answer the question "What is Chemical Engineering?",
b) name the major professional organizations in chemistry and chemical engineering,
c) efficiently use computer packages such as MSWord (including the equation editor and table function) and Excel, which are used extensively in industry and throughout the curriculum,
d) calculate rudimentary statistics, along with the concept of total quality management (TQM),
e) prepare a plan of study (course sequencing) for their next three to four years at TSU,
f) work problems using a concise systematic approach in a team environment,
g) undertake open-ended problems utilizing the engineering design process.

Success in achieving these objectives is discerned from a student's performance on both the homework assignments and the in-class group-based learning activities.

The main challenge in teaching *Introduction to Chemical Engineering* is providing the proper balance of academic rigor, while endeavoring to get students excited about the challenging subject matter comprising the ChE curriculum. Classes that meet just once a week do not afford frequent interaction between students and instructor, but this may actually preclude the course from becoming a boring routine.

Students typically come from a wide rage of educational backgrounds (private prep schools in large cities vs. tiny rural public schools). Thus, students come into the program with differing academic exposure based on environment. Significant variability is also seen in student ability, motivation, and time commitment. None of these extremes, however, represents significant social diversity (cultural, marital status, age, etc.). Thus, one of the challenges is to promote an appreciation of diversity in a class comprised of primarily eighteen year old, rural Midwestern students.

The present course outline found in Table 1 begins with an introduction to the course and ChE. It quickly shifts to the development of computer skills and calculation of statistics. Students are then introduced, via lecture and plant tours, to chemical process equipment and the engineering design process.

Table 1. Introduction to Chemical Engineering Course Outline

Week	Notes/Homework	Topic
1	Why TSU? memo	Introduction & ChE as a Profession
2	MSWord & email	File Management & MSWord (Eqn. Editor, Drawing, Tables)
3	Excel Equations	Unit Conversions (SI and Amer. Engg.) & MSExcel Intro
4	Excel Graphing	Stoichiometry & MSExcel Spreadsheeting
5	Tour Memo	**Plant Visit—Univertical Corp.**
6		Statistics in MSExcel
7	Excel Statistics	Statistics in MSExcel (cont.)
8	Time Mngt. Evaluation	Time Mngt. and Tour of Units Lab
9	Midterm (Take-home)	Temperature Lab
10	Four Year Plan	Curriculum in ChE at TSU & Co-op
11	Unit Op Investigation	"Orange Juice" lecture
	XXX	**SPRING BREAK**
12	Design Prob. Assigned, Soy Bean Science Demo	Problem Defn. & the Design Process/ Rubber Products
13	Tour Memo	**Plant Visit—Foamex**
14		Design (cont.) & Programming Skills
15	Design Prob. Due	Group Dynamics (Personality Profile/Survival Game)
	Design Presentation	**FINAL**

Miscellany: Outside speaker(s), Creativity (brainstorming), Videos (bio, materials, etc.)

The current text is *Introduction to Excel*[2]. It was introduced just this past semester (Spring 2000) to provide students both a structured reading resource during the course and a reference book for future needs. Previously, no text was required. The Excel reference manual was listed as a reference for the course, but this has not provided students with useful personal resource. Other texts have been considered; most notably *Elementary Chemical Engineering*[3]. However, departmental faculty believed, while rigorous, it did not convey a sufficient level of excitement about the subject matter to promote student interest.

Lectures are currently a combination of Deductive/Intuitive and Sensing/Inductive in nature. Lectures typically consist of exposition of a concept, derivation of any necessary equations, followed by didactic examples similar to those used in the required text or alternate sources. Throughout the lecture, I make a point of asking questions around the room (a different question to students around the room sequentially or randomly) to ensure that students are attentive and comprehending the material being presented.

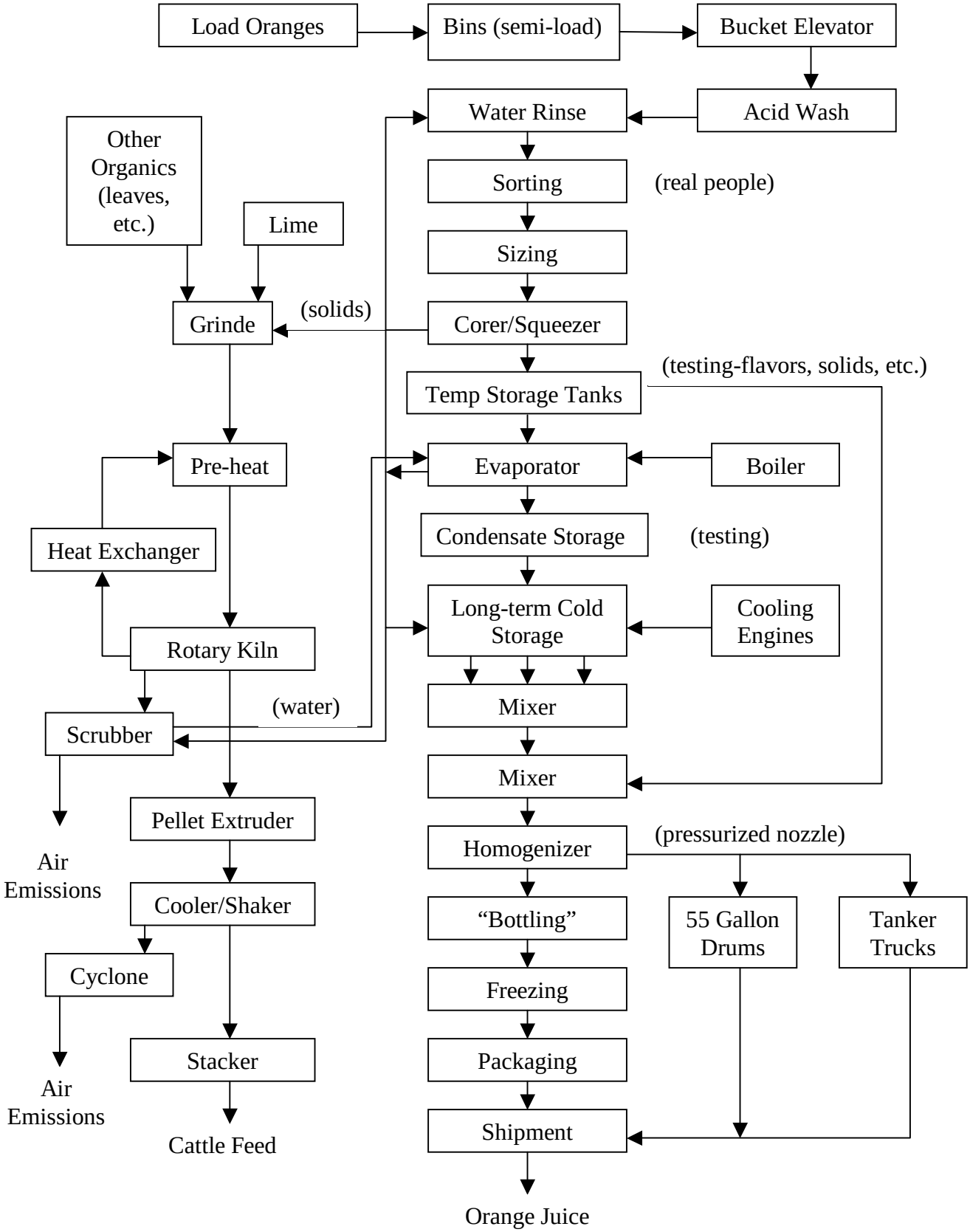
The emphasis of the course, however, is on hands-on learning activities. These range from activities as simple as the second hour of a class being spent in the computer lab to making gluep[4] as part of a lecture on polymers. Highlights of this course include the "orange juice" lecture, a tour of the unit operations lab and pilot plant, and field trips to local chemical process industries.

The "orange juice" lecture begins with a description of process flow diagrams and industrial chemical engineering equipment. The in-class activity for this lecture is based upon a plant tour of the DUDA-Citrus Belle frozen citrus juice concentrate plant in Hendry County, Florida. During this interactive learning activity, students are first presented with a problem from *Elementary Principles of Chemical Processes*[5], an introductory text on mass and energy balance, that introduces the concepts of recycle and bypass with orange juice concentrate production. Students are then asked to develop, from scratch, a block diagram of an orange juice concentrate plant. With some directed questions and prodding, the class is generally able to develop a schematic similar to that found in Fig. 1.

A tour of the department's unit operations lab and pilot plant is designed to pique student's interest in the hands-on aspect of the program and the resources that they will have at their disposal. It is also designed to visually reinforce the information presented in the orange juice lecture on industrial chemical engineering equipment.

The first off-campus field trip this past year was to Univertical Corporation in Angola, Indiana. Univertical manufactures products used in the electroplating industry. Observing the production of copper anodes gives students a perspective to the mechanical engineering field. However, the manufacture of copper sulfate (used in the manufacture of pennies), nickel sulfate, and the waste water treatment operations are of most interest to the students. At the conclusion of the tour, students are asked to summarize the tour in a one page, type-written memo.

Fig. 1 Orange Juice Plant Block Diagram



The second off-campus field trip this past year was to the Foamex facility in Auburn, Indiana. Foamex is the largest supplier of flexible polyurethane and advance polymer products in North America. The patented VPF^{TM} process creates a wide variety of proprietary foam products with precisely-defined physical characteristics used in automotive products, furniture products, cushioning products, and technical products (used to filter gases, liquids, and even molten metal).

Homework, as detailed in Table 1, is assigned each class. Homework is designed to take up to one hour a week in an effort to mitigate the fact that only one hour of credit is awarded for two hours a week in class.

Due to concerns about copying of solutions, the current collaboration policy is restrictive (except on team-based projects where noted), emphasizing the importance of individual effort. Assignments that prove difficult for the majority of the class are reviewed during lecture.

A single mid-term exam is given. This exam is designed to insure that students have a solid grasp on their chemical engineering plan of study, including specific requirements that must be met prior to graduation. In particular, a firm grasp of social science and humanities (SHS) requirements, historically one of the most challenging advising concepts, is tested. For this test, students are presented a number of course combinations and are asked if these combinations satisfy the rigorous SHS requirements. In addition, students are presented a partially complete program of study in SHS and asked to identify future classes that will meet the requirements most expeditiously. Students present their design project findings during the final exam period displacing a comprehensive exam.

Recent design projects have included redesigning the paper clip[6] and this past year's project to develop a water bottle rocket that will fly the furthest[7].

Final grades are determined from a weighted average of scores on homework (60%), the midterm (20%), and the design project (20%). Up to 5% extra credit is given for various projects/assignments, including attendance at the AIChE student chapter meeting.

IV. Longitudinal Retention in the Chemical Engineering Department

Modifications made to *Introduction to Chemical Engineering* in the conversion from a quarters-based academic calendar to one based on semesters has had a dramatic impact on the subsequent retention of chemical engineering students in the program.

A graph of longitudinal ChE enrollment by class for the past four years (some partial) is presented in Fig. 2. This figure shows a precipitous decline in subsequent year's enrollment by students taking the course in 1997. (Students are defined to have entered the program by registering for *Introduction to Chemical Engineering*. There is little that can be done to mitigate student attrition prior to this expositional course.) Significantly more gradual declines in subsequent student enrollment are evident for students taking the course in 1998 and 1999.

Information of the percentage of ChE students retained in subsequent years is presented in Fig. 3. This data is provided for students enrolled in *Introduction to Chemical Engineering* the previous three years, by year. Again, this figure shows a precipitous decline in subsequent year's enrollment by students taking the course in 1997. For students enrolled in 1998 and 1999, subsequent year's retention has averaged at roughly 80 percent for both frosh to sophomore (FR/SO) and sophomore to junior (SO/JR).

V. Conclusions

The recent conversion from quarters to semesters has facilitated the development of a two-course sequence designed to introduce the student to the chemical engineering field. This new course sequence has dramatically improved ChE student retention the past two years. First year retention in the program has jumped from 44 percent three years ago to approximately 80 percent the past two years. *Introduction to Engineering* exposes students to other engineering fields of study and university resources available to assist the educational process, while *Introduction to Chemical Engineering* focuses on teaching students spreadsheeting skills and more formally introducing them to their chosen academic field. In the second course, a variety of "hands-on" and expositional learning activities are used to excite the students about the rigorous, but rewarding, academic program on which they are about to embark.

Fig. 2 Longitudinal ChE Enrollment by Entering Year Tri-State University 1997-2000

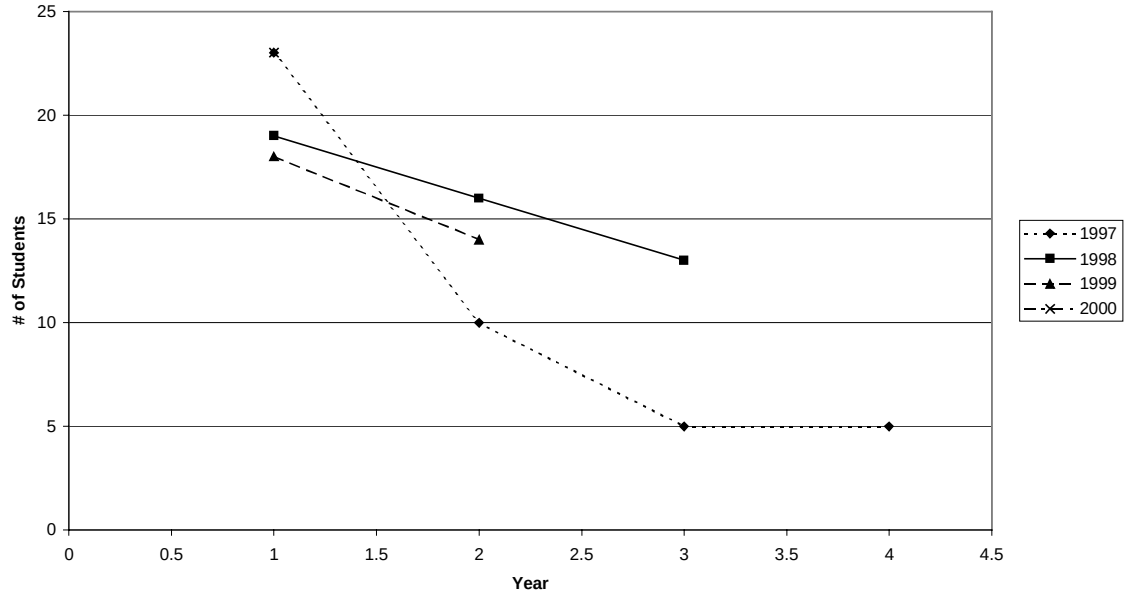
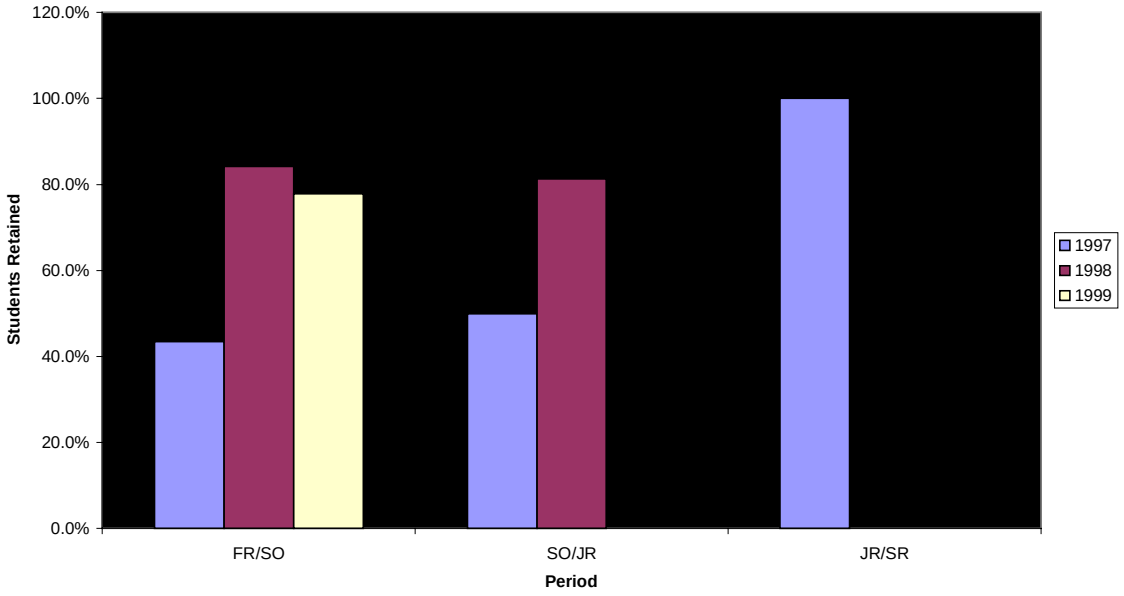


Fig. 3 Longitudinal ChE Retention by Entering Year Tri-State University 1997-1999



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