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ABSTRACT

This paper focuses on curriculum development in higher education and gender differences in science, mathematics, and engineering education. Females attribute their problems to not being smart enough to handle the course materials; however, males attribute their problems to poor teaching or the course materials. Classes themselves and the internal curriculum are other sources of student complaints. The real issue goes directly to pedagogy. (Contains 18 references.) (YDS)

Factors Influencing Retention in Introductory Biology Curriculum

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Introduction

Retention in higher education has long been an active area of research (Astin, 1964; Tinto, 1975), and currently remains a concern (Bank et al, 1994; Eaton and Bean, 1995; Nora et al, 1996; Dana Center Report, 1998). However, as Braxton and Brier (1989) stated, "Researchers are far from understanding the causes of college student attrition" (p.60). One of the most tested theories has been put forward by Tinto (1975). His retention model posits that a student is more likely to persist if they are integrated into two areas of college life- social and academic. This model has been revised over the years (Tinto, 1987, 1993), but remains essentially the same. This study uses Tinto's model as its base, but expands its use beyond general retention of students at a college or university to retention within a disciplinary area. While there has been much research into retention in science and engineering, most retention models are not tested at the disciplinary level. Instead, they are used to predict retention in the college or university as a whole. The current study considers the role of the curriculum structure as part of the academic integration of biology students and its resulting effects on the retention of biology majors.

One goal of this study is to lay groundwork for intentional consideration of the development, implementation and evaluation of curricula in higher science education. The first step, development, requires goals and objectives for the new curriculum be clear, concise and measurable so that the third step, evaluation, can occur. Often though, the pressures inherent within a department or college push the curriculum committee quickly through development to the second step of implementation, causing evaluation to be overlooked completely until the next round of reform.

Retention in Science, Mathematics, and Engineering

Research shows that persistence among Science, Mathematics and Engineering (SME) majors remains below the average of other disciplines. Up to 60 % of entering students who identify themselves as SME majors early in their college career switch to other majors. Seymour and Hewitt (1997) looked at various factors that contribute to this high rate of switching. They identified a number of factors related to curriculum, advising, or high school preparation, including: 1) Lack of/ loss of interest in science, math and engineering, 2) Inadequate advising or help with academic problems, 3) Curriculum overload, fast pace overwhelming, 4) Discouraged/ lost confidence due to low grades in early years, 5) Conceptual difficulties with one or more SME subject(s), 6) Inadequate high school preparation in subjects/study skills, 7) Unexpected length of SME degree, and 8) Morale undermined by competitive SME culture.

SME majors have historically understood that their majors were hard (Shamos, 1995), and persistence within those majors represented a task which separated them from other students at the post-secondary level. For many years, faculty and students alike conceded a survival-of-the-fittest mode was at work. Making classes difficult was viewed as necessary in order to insure that only the best students remained in those majors. The fallacy with this type of attitude, however, has been borne out in recent research which contradicts the idea that the best students remain SME majors while less fit students move to other majors.

Ware, Steckler and Leserman (1985) were among the first to challenge the idea that some students, women in their study, were not as fit as those students who continued as science majors. Using a group of entering freshmen composed of both males and females with similar SAT verbal and SAT mathematics scores, they found distinct differences between males and females and whether they majored in science by the end of their freshmen year. There existed a significant difference between the sexes in choosing a science major (50% of females and 69% of males), and the predictive factors differed between the sexes as well. Females were more likely to major in science if they had highly educated parents, had high SAT mathematics scores, showed a strong desire for prestige and influence, and desired positive interactions with others. Only two predictive factors suggested males would major in a science, and they were high grades in freshman science courses, and being certain about the choice of a major before entering college.

When females did experience problems in science courses, they more often attributed the problems to themselves, suggesting they were not smart enough to handle the concepts being taught. Males attributed difficulties to poor teaching, or course material they perceived as extremely difficult. Ware et al (1985) suggest that females, "anxious to minimize the possibility of failure on a situation where they feel at a disadvantage...may develop extremely, perhaps even excessively, high standards for themselves as a prerequisite for staying in science" (p. 79).

Tobias (1990, 1992), and Rigden and Tobias (1991) considered science class experiences and discovered that students found the pace too fast, the concepts less important than the vocabulary, and assessments poor measures of their knowledge. All the students interviewed described the classroom atmosphere as competitive so that working or studying with other students was tacitly discouraged. This left slower students behind and frustrated other students as well. Students generally found faculty unapproachable or uninterested when visited during office hours. Even those faculty who were interested in seeing students did not have many suggestions to help students better understand concepts.

Role of science curriculum in retention

Just as researchers found that the culture of science varied little between institutions, so too did Heppner, Hammon and Kass-Simon (1990) find that biology curricula varied little between institutions regardless of concentration area, size of the institution, or primary mission of the institution (e.g. research, comprehensive, liberal arts). Outside of biology courses, most curricula also require specific classes in other science disciplines, including both general chemistry and organic chemistry, physics and calculus. Their study did not consider curricular issues that might vary between schools such as the relationship between lectures and laboratories, the order of classes taken, or the number of prerequisites required.

Seymour and Hewitt (1997) found that the pace and work load of the science curriculum played an important role in switching decisions for many students. Two factors were associated with the external curriculum, that is, the courses common to all students within a major while others related to the internal curriculum which individual instructors implement within their classes independently of other faculty. The two external factors included taking too many math and science classes in one semester, and the strict sequence of courses required for math and science disciplines. Students who took several math and science courses experienced overloaded schedules due to laboratories worth only one credit hour, but required 3-5 hours a week in class. The sequence of courses necessary for a science degree often did not allow a student to easily make up for a missed course or dropping a course. Because of the hierarchical nature of most math and science courses, carrying information from one class to the next in sequence is imperative for success. Unfortunately, many schools can not offer every course every semester, so a student needs to plan their schedule early and assume he/she will be successful in each course and limiting student choices from the first semester.

The researchers also noted the complaints students had about the classes themselves, or the internal curriculum. These included doubts about choice of the material covered, failure to teach or test what had been chosen, the lack of relationship between lecture and lab, and expecting TAs to cover extra material. Even if students were able to enroll in the classes they needed, there was another hurdle within the class itself they had not anticipated- attempting to guess what material was important and what was not. The real issue comes down to pedagogy, however, "the difficulty for faculty would appear to be that of redefining something as 'a problem' which has long been taken for granted as an appropriate and normal consequence of a pedagogy that serves established and largely unchallenged student selection objectives" (p.391).

The authors acknowledge switching itself is not a problem if it is caused by underpreparation, lack of interest, by discovery of another interest in another discipline, or by simply making the wrong choice. Unfortunately, their results found no distinguishing factors between switchers and non-switchers, therefore they suggest that th- roblems arise from outside the student through the structure of the educational experience and the culture of the discipline. They grouped the switchers into two groups: 1) able students with an interest in math and science who became bored by teaching and curriculum, and 2) able students who were actively discouraged by poor teaching and the weed-out process and move on to majors they resent.

A study considering curricular differences by Sundberg, Dini, and Le (1994) found that biology students who learned fewer concepts in their semester long class had higher levels of comprehension and better attitudes toward science than students who learned more concepts. Especially striking was the study's comparison of biology majors to non-majors. By the end of the semester, the non-majors scored higher on the comprehension tests than the majors even though non-majors had covered less material and had started the semester with lower background knowledge scores. The authors were concerned about results from two of the attitude subscales which showed that the majors classes "appear to be fostering science anxiety among the students who selected themselves as potential majors" (p. 691), and seemed to separate science from everyday life much more than non-science majors. They assert that curriculum reform in higher education often seems directed at non-majors rather than majors, and they do not want to see the majors excluded from such efforts, especially since the pool of scientists and science educators will be drawn from the majors.

Hanson (1998) contends that the curriculum itself impacts graduation rates. His argument stems from what he calls the 'graduation rate paradox.' Despite the fact that the quality of the average student has increased at his institution over the last 30 years in terms of SAT scores, and that most retention programs work for those students they target, graduation rates have remained stable over that period of time. He cites curve grading in specific 'Gatekeeping Courses' as the reason for this.

Ruddock (1996) also examined the curriculum's effects on retention of students in SME majors. She found that students taking the prerequisite mathematics course, pre-calculus, were awarded As and Bs at lower rates in subsequent semesters of Calculus I and II than their peers who did not take the prerequisite course. In this case, the prerequisite course provided the barrier rather than the introductory calculus course itself. In addition, only 14.5% of SME graduates started with precalculus or below while 61.6% of SME graduates started with first semester calculus and 23.9% of SME graduates started with classes above first semester calculus.

She concluded that precalculus was not serving its function as a prerequisite. Ideally, prerequisites should prepare students for future courses. Her results show this was not the case. Students were not prepared, achieved lower grades in the future courses and were less likely to graduate with an SME degree.

Research questions:

1) Do changes in curriculum policies affect student outcomes as measured in pipeline flows?

2) Do changes in curriculum policies affect student outcomes as measured by grade distribution?

3) Which factors predict the success/failure of students under different curriculum policies?

Design/ Population

This study employed an institutional research technique first introduced by Ruddock (1996). In it, she considered the primary research questions from two perspectives: 1) Prospective analysis which looks at demographics and performance of students as they enter college until they graduate or leave, and 2) Retrospective analysis which evaluates students after they have achieved graduation in the field being studied. Results from the prospective portion are reported here.

The population from which the sample was drawn were students identifying themselves as life science majors or undeclared pre-meds at The University of Texas at Austin. The University has an enrollment of over 48,000 students with approximately 51% males and 49% females. The ethnicity of the student body is 65% white, 12.5% Hispanic, 3.6% African American and 11% Asian and 7.9% American Indian and foreign.

Students in the Division of Biological Sciences(DBS) look quite different than the University as a whole. Currently, there are 1953 students in DBS with 44.3% males and 55.7% females. The ethnicity of students in DBS is 54.9% white, 23.7% Asian, 15.9% Hispanic, 3.8% African-American and 1.2% American Indian and foreign. Students who have declared one of the twelve biology majors or are designated undeclared premeds by the time they take BIO 302 during the years of 1990-1997 are considered for the prospective analysis. Student records were the primary source of information. Only data from students classified as entering from high school, rather than transferring from another institution, are presented.

The courses addressed in the study include the introductory courses common to all biology or life science majors: 1) Biology 302- Cellular and Molecular Biology, and 2) Biology 303- Structure and Function of Organisms. A third introductory course, Biology 304- Ecology and Evolutionary Biology does not have any prerequisites. All chemistry courses are considered as one group, though most students took the majors introductory course as their first chemistry course. The policy changes implemented over this period include: 1) AP tests results are given grade credit without a diagnostic test at the university in Fall, 1991, 2) Biology 302 becomes a prerequisite for Biology 303 in Fall, 1991, and 3) one semester of college chemistry becomes a prerequisite for Biology 302 in Fall, 1996.

Findings

Since 1990, the Division of Biological Sciences has experienced a significant increase in the number of students admitted in the fall semesters (Figure 1). The total number of students has increased from 577 in 1990 to 858 in 1997. There has also been a change in the gender make-up of the entering students. In 1990, 53% of the entering first-year students were male and 47% were female. By 1997, females made up nearly 58% of the entering students in DBS. Over this same period, SAT scores of DBS students have ranged between 1165 and 1216 (Figure 2).

Between 1990 and 1997, changes occurred in the course taking paths as prerequisite policies were implemented. They are illustrated in Table 1 below. As curriculum policy changed over the years, there was a parallel shift in the semester certain courses were taken. The largest shift affected Biology 303 which was one of the first courses taken in 1990, but after the policy change, is typically taken after the first year of enrollment. Chemistry remains one of the first courses life science majors take, while Biology 302, shifted completely from the last course to the first course, and now, is taken near the end of the first year or the beginning of the second.

Table 1- Course- taking paths

	First Course(s)	Second Course	Third Course
1990	Chemistry	Biology 303	Biology 302
1991	Chemistry	Biology 302	Biology 303
1996	Chemistry	Biology 302	Biology 303

Table 2 illustrates the flow of students entering as freshmen in 1990, 1991 and 1996, through the two introductory biology courses. Two flows are shown for each year. The first illustrates the number of life science majors or undeclared premeds who received a grade in the course. The second considers only the continuing students. Continuing students are defined as both 1) receiving a passing grade (A/B/C/CR) in the two introductory biology courses, and 2) remaining enrolled as a life sciences major for at least one semester after the second introductory biology course.

With increasing prerequisites, the percentage of students able to move on to higher level courses decreases. In fact, the overall number of students completing the introductory sequence decreases from 241 students in 1990 to 188 in 1996.

Table 2- Pipeline for 1990, 1991, 1996

1990

1991

1996

Entering

481

481

460

460

546

546

Bio 302

399

241

446

348

427

292

Bio 303

455

322

352

239

321

188

83%

50%

77%

52%

59%

34%

The changes in grade distribution for students in 1990, 1991, and 1996 are found in Table 3. Three shifts are apparent. First, a dramatic decrease in A/B grades occur in chemistry after Biology 302 becomes a prerequisite for Biology 303, however, the grade distribution then shifts upward by 1996. The other two changes appear to be related. Biology 303 grades increase both times prerequisites become policy, in 1991 and 1996, and Biology 302 grades shift downward slightly after becoming a pre-requisite for Biology 303. Both of the observed changes are moderated, however, when Advanced Placement (AP) related grades are removed from the total distribution. In 1996, one third of all A's awarded in Biology 302 and one-fourth of all A's in Biology 303 were AP- related. With this correction, grades for students taking the classes at UT- Austin show decreases in the A/B distribution for Biology 302 and increases for Biology 303.

Table 3- Grade Distribution

1990

1991

1996

Chem

Bio

302

Bio

303

Chem

Bio

302

Bio

303

Chem

Bio

302

Bio

303

%A/B

63

53

47

52

49

54

63

52

69

- AP

63

51

46

52

46

52

62

43

55

Discriminant analysis was done for 1990, 1991, and 1996, to identify important variables that distinguish the continuing students from those non-continuing students. The list of the predictive variables is found in Table 4. A complete list of variables considered during the analysis is found in the Appendix.

Table 4- Predictive Variables

1990

1991

1996

Bio 303 before Bio 302

AP Hours

High School Rank

Pre 302 Hours

Bio 302 before Bio 303

AP Hours

No Chem before Bio 302

Pre 302 Hours

AP Hours

Bio 302 before 303

High School Rank

No Chem before Bio 302

71% predicted

79% predicted

74% predicted

In all three years, the sequence of the courses was an important predictor of success, and the influence of the AP exams increases over time. No demographic data, including gender and ethnicity, nor SAT scores, were found to be predictive. These are interesting findings for two reasons. In spite of a dramatic gender shift over the time investigated, the percentage of males and females classified as continuing closely mirrored the actual gender make-up of the entering students. SAT scores, especially the quantitative portion, are usually predictive in considering retention in math, science, and engineering. Most often, the science majors investigated are chemistry and physics, which have much stronger math requirements and components. These results provide initial evidence that SAT math scores are not predictive of retention in the biological sciences.

The impact of AP testing on these results cannot be ignored. As more students entering the university have the opportunity to take these exams, it may become more important in predicting a student's success through the introductory sequence. In fact, the percentage of life science graduates with AP credit for the introductory courses has nearly doubled from 1994-1997 at UT-Austin. In 1994, 7.5% of graduates had AP Biology credit while 13.5% of the 1997 graduates received AP Biology credit. The percentage of graduates not taking the introductory sequence of courses will likely increase as the 1996 and 1997 cohorts move through the pipeline since higher percentages of these freshmen entered with AP credit.

As Seymour and Hewitt (1997) discovered, this study suggests no qualitative differences between the continuing students and those who do not continue. The only differences not attributable to curriculum structure were the number of AP hours and class rank. AP hours is often a function of the high school a student attends rather than a predictor of their academic preparedness, and while class rank is predictive, it explains only one to four percent of the variance between continuing and non-continuing students in 1990 and 1996.

Implications

The results of this study impact advisors, faculty, and administrators alike. First, advising students about course paths to graduation in biology needs to begin early in college if not in high school. Once students reach higher education, predictive models can help advisors to scaffold students who may not be as well prepared as their colleagues. If the AP test policies remain in place, college advisors need to make high school counselors and teachers aware of their impact.

Curriculum should be continually evaluated for its effectiveness. Presumably, courses are added/changed/required as prerequisites for two reasons, to insure content remains current and appropriate and to improve a student's success in succeeding courses. A plan should be in place to determine if these goals are being met. AP exam scores raise additional concerns here. If students with high numbers of Advanced Placement hours in math and science graduate at much higher rates in science majors than similarly prepared students without the benefit of AP courses, then policies concerning AP exams need to be reconsidered. Qualified students at schools without AP programs may be discriminated against since they must pay for and take classes which their colleagues do not.

Courses beyond the introductory sequence should also be examined for artificial barriers to graduation. While many introductory courses have reputations as 'weed-out' courses, some junior and senior level courses may also create difficulties. Seymour and Hewitt (1997) identified some troubling attitudes of seniors who would likely graduate in an SME major. Twenty-six percent were dissatisfied with their educational experience, and 38% had been "turned off to science." These results suggest that many problems lie beyond the first-year courses.

Administrators should treat the three steps of curriculum reform equally. Development of the curriculum should cite clearly defined and measurable objectives. Implementation of curriculum should not be rushed into, but should include input from faculty and students. Before implementation begins, an outlined plan for the evaluation of the curriculum needs to be in place. At the specified intervals, data for the evaluation should be collected, manipulated, and disseminated to the faculty involved in the implementation. Curriculum reform in higher science education requires evaluation of past and current curricula in terms of students outcomes in preparedness for future coursework as well as current material. It should be a team effort, bringing together faculty, students, advisors and administrators, to insure its success.

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