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ABSTRACT

Studies about engineering students and their success and attrition in college are numerous and diverse. One set of research efforts has focused on the differences between academically successful and unsuccessful engineering students. Personality characteristics, academic preparation, and work values are among the variables which have been analyzed in these studies. Researchers have used the Holland Vocational Preference Inventory, the Strong Vocational Interest Blank, and researcher-developed surveys and questionnaires to differentiate between persisters and nonpersisters. Although this past research may be used as a foundation on which to base current research, sample differences make it difficult to find a common thread among all the results. Self-analysis and local research are necessary to understand the students at a specific university. A second set of studies has focused on academic prediction and attempts to distinguish potentially successful students from those who will leave the field of engineering. An analysis of academic prediction studies indicates that the best method for differentiating successful from unsuccessful students involves multiple predictors such as grade point average, Scholastic Aptitude Test (SAT) or American College Test (ACT) results, interest inventories, and personal interviews. (NRB)

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Psychological Models of Engineering Careers:

Academic Prediction

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Abstract

The difference between successful and unsuccessful engineering students is discussed in terms of personality characteristics, academic preparation, and work values. An analysis of academic prediction indicates that the best method for differentiating successful students from unsuccessful students involves multiple predictors such as grade point average, Scholastic Aptitude Test or American College Test results, interest inventories, and personal interviews.

Psychological Models of Engineering Careers:

Academic Prediction

Studies about engineering students and their success and attrition in college are numerous and diverse. Most research focuses on the individual student and various characteristics which can be assessed and studied with psychometrically valid instruments or questionnaires which provide background information. A report of an investigation about college students who change their majors (Holland & Nichols, 1964) sums up the problems and asks several pertinent questions which must be asked by researchers who delve into the area of academic prediction with engineering students. Holland and Nichols classified students into one of Holland's six personality types, using engineering students for the Realistic category. In the conclusion the authors state:

> These findings...suggest several hypotheses about the recruitment and retention of students in engineering and science.... Engineering loses more students with potential for original work than the sciences do. Does this loss occur because engineering attracts many students who do not belong by virtue of their personal attributes? Or, does the typical highly structured first-year curriculum without electives drive out the student who needs, or is ready to do more independent work or research? (p. 242)

These comments reflect the major ideas and results of the literature in this area. Two major topics are discussed in this review, which also outlines specific recommendations which were made to the Civil Engineering Department at Texas Tech University in light of the literature. The first group of papers reviewed focus on the differences between academically successful and unsuccessful engineering students. Personality characteristics, academic preparation, and work values are among some of the variables which are analyzed in these studies. The second group of papers focus on academic prediction and the attempts to classify potentially successful students from those who will undoubtedly decide to leave the study of engineering. The two areas overlap in some respects, but it is safe to say that predicting a phenomenon is different from defining it, and prediction is facilitated by understanding the topic at hand. With this in mind, a careful review of the literature allows insight into success and attrition among engineering students.

Success and Attrition

Researchers have used a variety of methods to study the differences between individuals who persist in engineering studies and those who do not. Personality and interest inventories, achievement and motivation measures, grade point averages (GPAs), and questionnaires designed with the expectation that the answers would reveal pertinent information have all been given to students at differing times during their academic career.

Southworth and Morningstar (1970) administered the Holland

Vocational Preference Inventory (VPI) to a sample of 102 freshmen and 129 senior engineering students in order to examine the relationship between interests and one behavioral index, persistence in choice of college major. Two years after the VPI was given, the freshmen were divided into three categories: those who remained in engineering, those who changed major, and those who had withdrawn from the university. These categories allowed the researchers to look at profiles from freshman students who had not been exposed to the engineering curriculum in light of subsequent events. The method also allowed comparison between seniors and three groups of freshmen. The results indicated statistically significant differences among the three categories of freshmen on all six scales of the VPI. The authors also found that students who persisted in engineering studies displayed interest patterns similar to senior engineering students. The results of the discriminant-function analysis demonstrated that the VPI alone permitted the correct identification of approximately half of the freshmen who persisted in engineering, half of those who transferred to another major, and one-fourth of those who withdrew.

The Strong Vocational Interest Blank (SVIB), the predecessor of the Strong-Campbell Interest Inventory (SCII), has also been used to examine vocational interests and their development among engineering students. Following the theoretical framework set forth by Anne Roe and L. M. Terman, Kulberg and Owens (1960) addressed the role of motivation in scientific achievement and the usefulness of interest measures as valid group discriminators. The authors used a 100-item life history form and correlated the responses with the Engineering scale of the SVIB. The sample consisted of 111 freshmen mechanical engineering students. The results were used to develop a profile of the "typical engineer" from the analysis of the life history form. Only the information from students whose answers correlated significantly with the Engineering scale was used. The results indicated that the possessor of typical engineering interests had a history of unsuccessful personal-social contacts and adjustment problems, superior achievement in science courses, long term career planning, and liking to work with things and ideas as opposed to people.

Taylor and Hanson (1972) examined the relationship of vocational interests to persistence versus transfer from an engineering program by analyzing SVIBs administered at the beginning of the freshman and junior years. Students were classified as either transfers or persisters at the second test administration; those who had transferred were mailed the second SVIB. The results indicated that the total SVIB profiles of persisters as compared to those of non-persisters were not different to a statistically significant degree although there were some differences on two individual scales of the SVIB. The researchers concluded, first, that the persisters' SVIB profiles remained relatively unchanged from the freshman to the junior year, whereas the transfer students' interests were found to change dramatically during this same time period. Secondly, small but consistent initial differences between the two groups increased over the two years. The one question the authors could not answer was whether a change in interest led to change in educational goals or whether change in educational goals led to change in expression of interest.

Several studies have been conducted using the survey method and questionnaires developed by the researchers. Ott (1976) surveyed engineering freshmen who in the fall of 1975 were attending one of 16 schools which enrolled more than 30 female engineering students. The sample consisted of all the female freshmen and a random sample of male freshmen from the 16 schools. The survey included 1,291 females and 1,659 males. A questionnaire was administered which contained 230 questions, 200 from Part I of the College Student Questionnaire developed by the Educational Testing Service, and 30 items developed by the researchers. A total of 775 females and 905 males completed the questionnaire. The statistical analysis used nonresponse adjustment prodecures to minimize bias from this source. Ott discussed the results in terms of eight major categories: recruitment; family background and family relationships; academic background, attitudes, and achievement; academic expectations, plans, and goals; field choice and work attitudes; cultural and extracurricular interests and activities; social attitudes; and marriage and career preferences. In summary, few differences between men and women engineering students regarding recruitment or family background and relationships were found, but major differences were apparent in prior academic achievement, as well as academic expectations. Specifically, 40% of the women and 20% of the men were in the top 2% of their high school classes, and more women than men had high school grade averages of A or A-. Further, 44% of the men, but only 12% of the women, expected to do better academically than most students in engineering.

Dickason (1969) developed a questionnaire which focused on measuring awareness and commitment to the engineering major by new students. This questionnaire was administered as part of the admissions interview, which the author considers highly informative for both parties. The responses were correlated with first-semester GPA. The results strongly indicated that those students who knew what the engineering curriculum entailed and what engineers were likely to do when working in the real world were more likely to have a higher GPA and also still be enrolled after the first semseter. Dickason cited several problems with his study, including the fact that his construct of awareness and commitment may not be totally accurate, but he stressed the importance of an admissions interview for all candidates. This process allows both student and faculty to find out whether or not each is suited for the other.

Greenfield, Holloway, and Remus (1982) gathered extensive information on a sample of 322 male and 42 female engineering students and discussed it in terms of academic persistence, academic characteristics, family background, career information, and personal characteristics. Their results indicate that persisters differ from nonpersisters and that females differ from males in some areas. Basically, persisters have high academic aptitude in mathematics and science, high educational aspirations, available engineer role models, and perceived support from family, friends, and teachers. Females decided to enter the engineering field as a result of direct recruitment efforts more often than men, and they more often expected that the first semester in school would allow them to decide whether or not engineering was really the field they should be studying.

In a study analyzing admission policies and the question of how screening committees can best approach their duties, Christopher (1979) focused on scores of national examinations, class rank, and the satisfactory completion of specified prerequisites. Data were gathered over a five year period from students enrolled in a mechanical engineering (ME) orientation course. Information pertaining to subsequent academic performance was also obtained. The five factors used as predictors for retention rate were high school rank (percentile), ACT scores (mathematics and composite), and/or SAT scores (mathematics and verbal). The study revealed one salient factor: during the five year period, students leaving the University had a lower high school rank than those who remained in engineering. An average of 60% of all students were retained in engineering. Less than 40% of the students who left engineering did so for academic reasons. The majority of students who took the orientation course either graduated from ME or left the university entirely. The author concluded that the reported criteria used for admitting students appeared to be valid and certainly indicated that the freshmen who enrolled in the orientation course had the potential for obtaining an engineering degree. He attributed a difference in the retention rate of the 1975 ME class (47%) and the 1976 class (73%) to the weight placed on the selection criterion factors. Thus, he concluded that if only one factor is to be used in admission decisions, it should be high school class standing, since, regardless of the quality of high school education, class rank reflects the supremely important qualities of self-motivation, desire to excel, and willingness to put in the required study time. As a final concluding remark, Christopher addressed the problem of students who leave not only the ME department but also the university. If this pattern is true of most students, then engineering educators must focus some energy on counseling to re-direct these discouraged students. Christopher noted that if these students were admitted to engineering in the first place they may be quite capable of completing university level studies, even if they choose not to persist in engineering.

The characteristics of successful and unsuccessful students were also analyzed by Becker and Mowsesian (1976), Elkins and Luetkemeyer (1974), Elton and Rose (1967, 1971), Foster (1976), and Reid, Johnson, Entwisle, and Angers (1962). Each of these studies focuses on different aspects of engineering students; they all find differences between persisters and nonpersisters. The main point to keep in mind when reviewing this literature is that sample differences make it difficult to find a common thread among all the results. The implications for an engineering department which desires to understand the characteristics of potentially successful and unsuccessful students are quite clear: past research may be used as a foundation on which to base current research, but self-analysis is a must and cannot be circumvented. In other words, in order to understand the students at Texas Tech's Engineering Department, or any other specific department, an intensive local research effort is necessary.

Prediction

The subject of prediction has several major subtopics which are discussed here. Studies have been conducted on engineering samples alone, and on college samples, including all majors at particular schools. The common area involves predicting either college major or GPA using three different dependent variables. Examples of these are high school rank, achievement test scores, and self-expressed choice of college major.

Two studies analyzing the ACT's predictive value are especially pertinent. Using a sample of 328 engineering freshmen, O'Conner and McAnulty (1981) addressed the question of whether the majority of admissions criteria should center on ACT scores. ACT scores were correlated with first and second semester GPA and with overall first year GPA. The results indicated that 51% of the students' GPAs were predicted correctly (the exact letter grade), whereas 94% were predicted within one letter grade. In other words, the method used allowed the researchers to predict exactly where half of the students would fall with respect to GPA, and within one letter grade for almost all students. O'Connor and McAnulty cautioned that low ACT students should not be rejected as a matter of course. They neglected to discuss, however, an obvious possible reason for their robust results. The exact prediction resulted almost entirely from using data from students whose ACT scores were either above 24 or below 12. This method almost certainly causes a restriction of range in the sample and at the same time tells nothing about the students who fall between 13 and 23 on ACT scores.

Rowan (1978) studied the predictive validity of the ACT by using a sample of freshmen and seniors as contrasting groups. He divided the sample into all students in a four year program regardless of their academic standing, students who progressed normally and graduated on time, and dropouts. The ACT data predicted GPA with statistical significance in all groups; however, for the second group, graduation on schedule was predicted correctly at a level of greater practical significance. Rowan concluded that the ACT is a valid predictor of GPA and that better prediction is possible for females than males. No classification by major field of study was proposed in this investigation.

Using a somewhat less rigorous method, Stahmann (1969) asked whether self-expressed choice of major field of study at the time a student enters college can predict the major field at graduation time. He also looked at interest and achievement measures, but the focus was on self-expression of major field. Five different majors (N=100 per major) were studied, including engineering. For the engineering major, Stahmann found that the predictive efficiency of interest and achievement measures was relatively good, and that self-expression allowed correct prediction 92.8% of the time. Both of these results were statistically significant. Stahmann concluded that relative predictability is possible using these three variables, but noted that when attempting to elicit self-expressed interests the researcher must consider carefully the wording of questions asked in order to maximize predictive efficiency.

Statistical procedures for predicting student success at the university level are complex and varied. Neal and King (1969) compared a multivariate analysis with a configural analysis in an attempt to discover which one offered the better predictive procedure. Their sample consisted of 284 sophomores, juniors, and seniors, from four branches of engineering (chemical, civil, electrical, and mechanical). The students were administered the College Interest Inventory (CII) and were asked to indicate their satisfaction with engineering as a future professional commitment. The main purpose of the study was to see whether or not the two statistical techniques could discriminate between the four different branches of engineering. It was found that both procedures were able to predict a student's choice of engineering specialty. However, Neal and King preferred the configural analysis because it was able to discriminate almost equally across all levels with hits ranging from 70% to 80%. Multivariate analysis, on the other hand, was able to predict electrical engineers with 100% accuracy, but the rate for predicting chemical engineers was zero percent.

In a second study using discriminant procedures, Molnar and DeLauretis (1973) studied the mobility of engineering students throughout different majors within a university. They wanted to predict long range education-vocational decisions by using aptitude, achievement, and first semester GPA. Engineers were classified into five specialties: aeronautical, civil, chemical, electrical, and mechanical. The best discriminator for each speciality was found to be an interest inventory that was specifically related to that speciality. It was also found that predictors must be chosen in accordance with what a particular school of engineering defines as good academic status. If, for example, a school focuses on high GPAs as the primary indicator of good academic status, then academic variables such as ACT or SAT will be better predictors than interest inventories.

Several other researchers have investigated these questions using student populations. Each has found that there are factors which may aid in prediction, but none of the investigations used a method which can be conclusively identified as superior to the others (Juola, 1967; Munday, 1970; Scannell, 1960; Stahmann & Wallen, 1966). DeLauretis, Molnar, and LeBold (1972) criticized the concept of academic prediction and noted that past research had not accounted for variance in prediction studies. They pointed to the complexity of academic behavior as one reason for the lack of precision in its measurement, then offered a comprehensive statistical technique which should allow researchers to predict academic performance with more certainty than has been available in the past. The main point of departure is that DeLauretis et al. (1972) believed that GPA is largely unreliable and should not weigh heavily in prediction. In order to ensure academic prediction, several steps must be taken prior to undertaking educational research. The authors suggested a complex paradigm involving several different domain, variables, and relationahips.

The studies on prediction can give an engineering administrator several different methods with which to tackle a specific problem. It appears that the best method involves multiple predictors, such as GPA, SAT or ACT scores, interest inventories, and interview and questionnaires in which the student can express his or her goals and ideas. All of these can be of potential usefulness: the specific ones to be used must be based on the specific program or curriculum of interest, and, most importantly, must be based on the factors a particular faculty uses to describe the "perfect engineering student".

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