A Comprehensive Beginning Engineering Student Assessment Program

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Abstract

Since 1953, Purdue University's Department of Freshman Engineering (FrE) has pursued a wide variety of educational research programs that have focused on beginning students. FrE's current assessment of beginning engineering students and the freshman engineering program is fairly comprehensive. The FrE assessment strategy is to collect and analyze a data from a number of sources and of a variety of types and use triangulation of that data to develop an understanding of the programs strengths and weaknesses. These data include programmatic data such as retention data as well as initiative or program specific data. These data are collected in recurring efforts as part of longitudinal assessment and periodically to evaluate unique programs such as pilot programs. More resource intensive data collection means such as interviews are used to calibrate and validate the less resource intensive efforts that are carried out every year. This paper will document the development of a comprehensive assessment program that has evolved into a broad-based program that can be a model for an assessment program at any educational institution.

I. Longitudinal Assessment

History of FrE

When Purdue created Freshman Engineering in 1953, the new Dean of Engineering, George Hawkins, appointed Dr. Albert Spalding as Head of the Department. Dean Hawkins had just returned from a sabbatical leave at UCLA working with Dean L.M.K. Boelter, his Heat Transfer colleague and the creator of the UCLA's Unified Engineering Program. Deans Boelter and Hawkins had analyzed many articles in the Journal of Engineering Education and papers presented at ASEE that they felt were largely "arm chair philosophy." Dr. Spalding also just returned from a DuPont Year-in-Industry leave. Dr. Spalding and Dean Hawkins decided they needed more "hard data," and "action- oriented" programs; they appointed Bill LeBold in 1954, as a full-time Research Assistant in Engineering Education. Initially Bill worked under the supervision of his doctoral chair, Dr. H.H. Remmers, Director of Educational Reference, a testing and educational research division at Purdue University.

Bill LeBold began by analyzing a survey of industrial leaders on their views of engineering graduates and their curricula [1,2]. He also helped develop a new university-wide faculty orientation and a seminar in engineering education for new engineering faculty. He also conducted a comprehensive follow-up study of Purdue Engineering Graduates from 1911-1956.

Purdue Pre-Engineering Program Evaluation

To focus on the beginning-engineering students, an open-ended survey was conducted at the end of their first semester. This survey was the foundation for the Purdue Pre-Engineering Program Evaluation survey that has been used in various formats since 1957. It provides information on beginning student perceptions of the quality of first year courses, university facilities, first year counseling, placement, and special programs. Table 1 provides an example of trends in service ratings for ten years (1989-1999).

Table 1. Percentage of 1987-98 First Semester Freshman engineers who evaluated freshman engineering services as "excellent" or "good"

AREA	89	90	91	92	93	94	95	96	97	98	99	*NO. IN 1999*
Overall Pre-Engineering Program	84	80	80	85	81	80	82	78	74	78	76	*783*
Computer Facilities	NA	NA	NA	NA	NA	73	77	71	69	76	76	*1196*
Courteous and Friendly	NA	NA	NA	NA	NA	63	65	67	74	72	72	*1106*
Spring Registration	65	61	60	65	65	63	66	64	69	57	67	*1203*
Academic Climate	NA	NA	NA	NA	NA	67	66	76	68	68	66	*1059*
Fall Registration	71	66	64	70	66	64	65	66	65	64	66	*1157*
Day-on-Campus	67	63	61	65	61	58	60	59	64	63	65	*1058*
Engr. General Education Program	NA	NA	NA	NA	NA	62	63	60	64	61	62	*930*
Freshman Engineering-in-General	66	63	64	70	66	65	68	65	65	65	60	*1182*
Availability of Counselors	64	63	59	63	61	57	63	53	59	61	59	*985*
Placement this Semester	56	57	55	63	58	57	56	56	60	57	59	*1081*
Academic Advising	48	43	46	52	52	43	48	48	50	49	55	*1119*
Use of Student Counselors	44	41	33	48	49	42	45	46	47	49	51	*794*
Availability of Tutorial Help	38	38	44	48	45	49	53	50	47	46	46	*688*
Career Counseling	34	31	36	42	44	36	39	39	40	40	46	*778*
Help-Selection of Engr Major	33	34	36	36	40	32	36	40	40	38	46	*869*
Help-Selection Non-Engr Major	24	23	21	30	28	24	25	28	32	31	40	*467*
Purdue Interest Questionnaire	34	41	29	32	30	30	30	30	37	34	34	*1069*

Freshman Engineering Information Form

Placement of beginning students in initial courses in math, chemistry, physics, communications, and more recently in computer classes is critically important. The 1500-2000 students who start in engineering at Purdue from all over the world have great diversity in their pre-college preparations. In a wide variety of retention and grade assessment studies of admissions information, pre-college course grades, test scores and other background factors, grades in beginning level courses were identified as the critical elements related to student success [3,4,5,6,7]. A multifaceted placement program was developed to optimally place students in beginning math, chemistry, physics, computer, and communications courses. A by-product of those background studies was the development of a Department of Freshman Engineering Student Information Form. The information provided another way to examine trends in the characteristics and background of beginning engineering students. Data are collected not only on pre-college academic courses and computer experiences but also on outside activities, honors,

career plans, and parents' education and occupation background. This information is collected confidentially and is used only for counseling and research studies.

Purdue Engineering Data (PED)

Another area of considerable interest is engineering and university retention and graduation rates. FrE research studies have consistently shown that retention and graduation rates of beginning engineering students had to be viewed longitudinally [8]. Comparing the number of students retained in engineering or in the university could not be determined by examining the nominal numbers of engineering in the first, second or even the third year. These estimates were grossly inadequate because of the great mobility of students in and out of engineering and the university. We also recognized that engineering and university graduation in four years was an oversimplification. Trends in grade inflation and deflation, changing academic standards, the impact of honors and high-risk tutorial programs, women and minority programs also needed careful monitoring and evaluation [9,10]. As a result, we began to develop a comprehensive Purdue Engineering Data (PED) base that followed each beginning undergraduate engineering student for 10 years (20 semesters). PED includes admissions information, pre-college information (collected on the aforementioned Freshman Engineering Student Information Form), transcript information (course grades, semester/cumulative grade point averages, engineering and university retention and graduation by semester). PED enabled us to examine not only trends in the demographic, pre-college, and college characteristics of Purdue beginning engineering students but also to make comparisons by gender, ethnicity, socioeconomic status, and participation in honors and high-risk programs.

FrE can use PED for comparative and benchmark studies with other engineering institutions. The National Science Foundation provided educational research funds to conduct a National Career Development Study to collect longitudinal data from a representative national sample of beginning engineering students that enabled us to examine the characteristics of students, transfers, and withdrawals in U.S. Engineering Colleges. We found many of the factors identified with retention at Purdue were similar to those found at other engineering institutions. Two major findings emerged from that study: 1) first semester grades was the best overall factor related to engineering and college retention and 2) interests was the most relevant non-cognitive factor related to transfer within engineering fields or transfer to non-engineering fields.

Special programs that focused on the Freshman Engineering Experience were developed that focused on improving grades during the critical freshman engineering year. Action oriented programs emerged not only at Purdue but also nationally, as the engineering community attempted to meet new challenges. Falling and rising engineering enrollments coupled with increasing concerns regarding equity issues for women, minority, and human rights resulted in engineering institutions giving increased attention to recruitment and retention. An honors program, a counselor-tutorial program, a women engineering program, a minority engineering program, and more recently an international engineering program were developed. Significant efforts to improve academic achievement during the freshman year are the hallmarks of most of these programs.

Purdue Interest Questionnaire

The Purdue Interest Questionnaire (PIQ) was developed to provide students with information that helps them make career decisions within engineering fields as well as related non-

engineering fields based on an important non-cognitive factor: their interests. The PIQ helps students compare their interests with engineering students and graduates majoring in various engineering fields and with students majoring in other science, technology, and management fields. The PIQ has students rate their interest in a list of school subjects, occupations, activities, job functions, and types of employers using a 3-point Likert scale of (L) like, (I) indifferent and (D) dislike. A wide variety of studies have been made to establish the PIQ's differential validity. The PIQ is used not only at Purdue but at many other engineering institutions. Appendix B includes a copy of a typical PIQ profile.

First Semester Placement

The placement into the appropriate first math course is a key to student success. As a result, all incoming students are currently given a placement test on Algebra and Trigonometry skills during their summer registration visit. Passing this test is a prerequisite to entry into calculus. Studies of placement test and other pre-engineering factors versus first semester math and chemistry grades have enabled FrE to establish first semester placement guidelines.

A Web based diagnostic tool is currently being piloted that will enable students who have been admitted to Purdue to self-evaluate their algebra-trigonometry skills prior to their summer visit to campus to register for fall classes. It is envisioned that the self-evaluation process will assist "at-risk" students by helping them discover their deficiencies prior to their arrival on campus and allow them to seek appropriate remediation in a timely fashion.

II. Short Term Continuous Assessment

Course Evaluations

Summative Course Evaluations

The cornerstone of the FrE program is the set of courses that the students take. Assessment of the courses includes traditional, summative course and instructor evaluations. These evaluations use Likert-type scales that rate seven course and eight instructor aspects of the course. The evaluations are administered at the end of the semester. Open-ended questions are included to obtain qualitative responses from the students, especially with regards to achievement of course learning objectives and what is helping or hindering student learning.

Formative Course Evaluations

Other means of assessing the courses using formative means have also proven successful. One mechanism used in the large (1400 students) first semester computer course is a mid-semester evaluation. The students are asked to evaluate their graduate and undergraduate teaching assistants, the course coordination, and the effectiveness of the student teaming experience. Results are returned to the Director of Laboratory Instruction. In this way, teaching assistants issues are dealt with in a timely manner and corrected mid-semester.

Another mechanism that has proven effective in the large-classes is the use of class-representatives. One student is chosen from each recitation or lab division. The representatives meet with the lecture instructor once a week to provide feedback from the lab section on the

lecture and lab experience. This has met with a great deal of success and has provided the students with a direct voice and the instructional team a means to evaluate anecdotal feedback.

Active learning in the lecture of large engineering courses provides a ready means of collecting feedback from students or student teams on the course. Specific questions designed to identify concerns such a significant hang-ups with course content are posed and responses are collected anonymously or by student teams. This is done at different points during the semester and enables quick response to course mechanics troubles.

Assessment of Course Initiatives

Whenever substantial or unique course changes are made, as assessment process is established to determine the effectiveness of the change. For instance, formalized teaming was introduced in the introductory problem solving and computer tools course. Student team logs and peer evaluations, mid-semester and summative course evaluations are being used to evaluate the success of the implementation.

Early Warning System

One of the proactive assessment tools that FrE uses a D/F List which tracks student performance in chemistry and mathematics courses. These courses have been closely correlated with success within engineering. As a result, problems in these courses are addressed early to assist students in the successful progression through the program. A system has been put into place where after the first and second exams, a list of students who scored a D or F are returned to FrE. The student exam grades, homework scores, and quiz scores are included in the report. Students appearing on the D/F List are contacted and asked to make an appointment with an advisor to talk about their progress. This program has been a tremendous help in identifying problems early and allowing students to take corrective action and in many cases improve on their early performance during the semester of concern.

Parent Feedback to FrE

A new dimension to the FrE assessment program has recently been added. An electronic newsletter is now being sent to parents at regular intervals throughout the first year their child is at Purdue. As part of this newsletter, a parent survey is administered towards the end of each semester. The data yielded using this assessment tool provides us with the parents' perspective of the FrE program. This data is used to triangulate the data acquired from the students directly and to obtain a more accurate picture of the program as a whole.

III. Special Programs Assessment

Summer Mathematics Bridge Program

The Summer Mathematics Bridge Program is a intense one week mathematics review program designed to help freshman engineering students identify and overcome weaknesses in algebra and trigonometry attributed to their high school education. The goal of this program is to elevate each student's high school mathematics background and prepare each student to succeed in the required university level math sequence. These students are identified during summer registration by their Purdue algebra/trigonometry test scores followed by their high school math

grades and SAT scores. The one-week program occurs the week before the fall semester begins and focuses on:

- reviewing algebra and trigonometry,
- acquainting the students with the pace of a college course,
- enabling the student to discover the time and effort required to succeed in a college course,
- introducing student to methods for improving study and test taking skills,
- facilitating the formation of group study partners, and
- orienting the students to the Purdue campus.

The assessment of this program has two foci. First, the performance of students enrolled in the program is tracked throughout the FrE program and compared to students who entered FrE with similar math backgrounds but chose not to participate in the program. It is envisioned that this data will be used to better identify the target audience for the program and indicate the long-term impact or success of the program. Second, the students periodically throughout the program evaluate the quality of instruction, content, and problem solving periods. The students also complete an overall program evaluation at the end of the program. These evaluations will be used to improve the program for the following year.

Seminar for Top Engineering Prospects Summer Program

The goal of the Seminar for Top Engineering Prospects (STEP) Summer Program is to provide students who are moving from their junior to senior year in high school the opportunity to explore what the various disciplines of engineering are and what career paths they may eventually seek. The program is a weeklong experience at Purdue's West Lafayette campus with participants investigating various aspects of engineering and college life through a series of tours, demonstrations, classroom experiences, and projects. Since the computer is a fundamental tool used by today's engineer, students have the opportunity to solve elementary engineering problems using software packages like Excel®, MATLAB®, and the like. Other sessions during the weeklong experience include: labs tours and demonstrations from the various schools within the Schools of Engineering, plant trips to local industry, a chemistry show designed to peak a students interest into the marvels of chemistry, and various hands-on engineering projects.

A detailed assessment that examines current trends in the participants demographics, pre-college preparation, influencing factors regarding the college and major selection process, as well as the effectiveness of the program is performed using a pre- and post-survey. The pre-survey solicits information about a participants background including: family history, prior academic instruction, plans for college, perceptions about engineering, and what they expect to learn as a result of attending the summer program. A post-survey is administered to evaluate the program's effectiveness towards helping the participants understand what engineering is, what engineers do, and what college life is like. In addition, the post-survey is used to evaluate various aspects of the program including: social/recreational activities, the design project as related to teaching engineering concepts, and their impression of working as a member of a technical team.

Learning Communities

In order to facilitate an easier transition from high school to college for incoming students, the Department of Freshman Engineering has piloted two Learning Communities. In these two communities, the students are co-registered in four courses with 23 other students. A total of 48 students participated in two cohorts. Student within the same cohort attended the same chemistry, freshman engineering seminar, math, and computer sections. The Learning Communities are being evaluated using retention and student grade point averages to measure

academic success. These data are being compared against students with similar incoming profiles (SAT, high school grades, and class rank) who were not assigned to the learning community cohorts.

The Indiana State University Quality of Life Questionnaire (originally the Community Experiences Questionnaire) is also being used to assess the effectiveness of improving the transition to college [11,12]. A pre- and post-test are administered to the students in the learning community cohorts at the beginning and end of the semester, respectively.

IV. Special Assessment Initiatives

Lilly Endowment Retention Initiative

As part of a campus-wide retention initiative, data are being collected from students enrolled in first year seminar courses. In addition to FrE, departments that are participating include Biology, Education, Animal Sciences, Computer Science, Pharmacy, Naval Sciences, Chemistry, and Health, Kinesiology, and Leisure Studies. Data are also being collected from students enrolled in courses on one of the Purdue regional campuses. In addition to GPA and retention data, two surveys are administered to the students to measure academic intrinsic motivation and institutional integration. The Academic Intrinsic Motivation Scale (AIMS) [13] is used to assess motivation. This survey is administered at the beginning and the end of the fall semester and consists of subscales that examine control, curiosity, challenge and fantasy. The Institutional Integration Scale (IIS) [14,15] is used to measure the integration of the students into college life. This survey is also administered at the beginning and end of the fall semester. The scale consists of subscales that examine peer-group interaction, interactions with faculty, faculty concern for student development, academic and intellectual development, institutional and goal commitments. These data are being matched with control groups of students who do not take first year seminar courses to ascertain the benefit of these courses on the Purdue campus.

Student Voice

A detailed assessment of the Freshman year was begun with funding from the GE Fund. The goal of this assessment was to understand the student perspective or voice as well as assess the overall health of the program. To accomplish this, in-depth interviews were conducted with 31 faculty and staff in the Schools of Engineering and 15 faculty and staff in the School of Science who represent approximately 750 years of combined teaching experience at Purdue. Interviews were also conducted with 13 employers of co-op and intern students in an effort to ascertain their perspective on the freshman program. These interviews were transcribed and analyzed. The goal was to provide the faculty who provide the courses that contribute to the FrE program and the faculty who teach courses that build upon the freshman engineering year a multi-dimensional perspective of the freshman engineering experience. Assertions concerning noted changes in the students and the curriculum, needed changes in students and curriculum, and student strengths were distributed to the Dean's Offices and departments for discussion. The core of this study was a set of interviews with 97 freshman engineering students collected over the course of the 1998-99 academic year, from shortly after the first set of exams in the Fall semester until just before final exams in the Spring. These interviews were transcribed to yield a data set of roughly 1500 pages of single-spaced transcripts. Analysis was done, in part, with the QSR Nud-ist program [16] to examine eight nodes: students' experiences in high school; their reasons for choosing to come to Purdue; their reasons for choosing to major in engineering; their perception of student

life at Purdue; academics at Purdue — with particular emphasis on their chemistry, mathematics, physics and engineering courses; their perception of academic responsibilities of both students and their instructors; their perception of the women in engineering and minorities in engineering programs; their perception of the overall engineering program; their perceptions of studying, including how and how long they study and differences in the way they study for different courses. Analysis of interviews was recently completed and discussion of the results of these interviews will dominate meetings of the faculty team from Science and Engineering over the Fall 2001 semester.

Survey data were obtained during the same semesters that the interviews were conducted in order to be able to use the data to triangulate the interview data. From a sample population of 805 students, roughly half of the total population of freshman engineering students during the Fall 1998 semester to probe students' perceptions and views about a variety of issues including their academic preparation for college and the first-semester experience at Purdue [17]. The analysis of responses was broken down into thematic sections: background variables such as student perceptions of how well high school prepared them for college work and the reasons why they chose to come to Purdue; their perceptions of the general academic and social support provided through orientation programs and interactions with their academic counselors; their expectations and experiences during course work; and their study habits, such as how and how long they studied for exams. Secondary statistical analysis was applied to examine variations in responses by demographic variables of GPA and predicted GPA.

The collaborative effort between engineering, science, and education to evaluate the freshman year has opened lines of communication that may be as valuable as the data itself. The data has reinforced the strengths of the current program. Purdue's program attracts some of the top engineering students and the result is outstanding engineering students and engineers. However, the freshmen have pointed out opportunities for improvement. Students have a relative easy time adjusting to campus and assimilate quickly. They feel adequately prepared for their freshman courses based on their high school experience. Employers of coop and intern students favorably compare the Purdue students with those from other universities. The freshmen do not see the connections between courses in science and engineering. That has prompted discussion of how to integrate and/or coordinate topics taken in the common courses. The student reactions to the cooperative learning experiences they encounter in the freshman year vary significantly reflecting the diversity of these experiences. The faculty of the engineering schools felt disconnected from the freshman year and, in many cases, were unaware of what occurred in the freshman year. The faculty from science and engineering felt that it was important to introduce more critical thinking and problem solving in the classroom [17].

Conclusion

Freshman Engineering is concerned and cognizant of the number and timing of the various student surveys and questionnaires. Most of the surveys, tests, inventories used in Purdue's comprehensive assessment program are conducted with a bonafide purpose and are generally supported by students. We assure students that their "individual responses will be held confidential" and that we do make use of the results. Participation in all research assessments is voluntary, and participation rates are high, generally from 70-95%. Our incoming survey of beginning students is used to assist us in placing students in beginning courses and to help counselors personalize initial contacts with students. Students that complete the Purdue Interest Questionnaire (PIQ) get their own personal profile of the results. Course and Teacher

Evaluations were initiated in response to student, faculty, and administrative demands. Student reactions to the occasional and sometimes frequent requests to complete surveys, questionnaires, tests, etc. tend to be neutral to favorable, although there are sometimes negative reactions by students. In one of our national studies, engineering students completed two interest inventories and a survey that combined required over 1000 item responses. Fifty percent of the respondents "Had no feelings one way or another", 25% "Enjoyed answering them", 11% "Felt some of the questions were much too personal", and 19 % made "Other" responses, such as "too long", "whew", and "would like a copy of the results" [18]. In some of our studies we do provide participants with a copy of the results as we did for the thousands of participants in our studies in 1956, 1965, 1981 and 1995. Providing copies of the results is often a great incentive, especially when the time demands are great and the resources available.

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Appendix A. Sample PIQ Results