

Lessons Learned When Assessing Learning: Hills and Valleys on the Road to Curricular Change

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Abstract

As part of an ongoing NSF/Department-level reform (DLR) project, the Office of Academic assessment collaborated with engineering faculty to develop an assessment plan for continuous improvement of the first-year engineering program. Multiple instruments and methods were employed to: (1) assess the knowledge and experiences of the engineering freshmen, (2) evaluate success in learning introductory engineering fundamentals, (3) develop curricular content and assess impact of on-going curricular changes and (4) predict engineering retention and cumulative G.P.A. This presentation focuses on factors related to retention and success in the freshman engineering program as well as assessment lessons learned.

Lessons Learned When Assessing Learning: Hills and Valleys on the Road to Curricular Change

A new Department of Engineering Education (EngE) was created within the College of Engineering (COE) at Virginia Tech (VT) in May 2004 to improve engineering pedagogy within the COE. Engineering freshmen (~1200 every year) at VT are required to complete a General Engineering (GE) (also called freshman engineering) program before they can advance on to one of eleven degree-granting departments. The EngE faculty are responsible for conducting the GE program. Another primary mission of the EngE department is to carry out rigorous research in the area of engineering education and support the research agenda as brought forth in the October 2006 issues of the Journal of Engineering Education. Such rigorous research efforts in engineering education require collaboration between engineering and education faculty within and outside the university. A National Science Foundation (NSF) supported planning grant under “Bridges for Engineering Education” program laid the foundation for such an engineering-education collaborative at Virginia Tech. One objective of the planning grant was to create a contemporary framework for undergraduate engineering pedagogy, beginning with freshman engineering experiences. The investigators of this planning grant (engineering and education faculty) proposed to reformulate engineering curriculum using a spiral approach (Bruner, 1960). This approach is adopted in a 4-year (2004-2008) implementation grant under a Department-Level Reform (DLR) program of the NSF (hereafter referred to as DLR project).

As part of the DLR project, a number of EngE faculty members are collaborating with faculty from other engineering departments and the School of Education to reformulate the freshman engineering program within the EngE and the bioprocess program within the Biological Systems Engineering (BSE) department using a theme based spiral curriculum approach. One of the objectives of the DLR project is to develop a continual assessment plan to

measure the impact of the reformulated curricula, faculty improvement activities, and student learning. To accomplish this, the DLR investigators are collaborating with the Academic Assessment unit at Virginia Tech to develop and implement various formative and summative assessment tools. This paper discusses the development and implementation of this plan, highlighting what was most effective, as well as, the lessons learned in hindsight. A central element of the new plan was a series of targeted assessments designed to identify likely predictors of success in the freshman year as well as ways to improve the curriculum.

Assessment Measures

Engineering Education New Student Survey. A New Student Survey was developed by the DLR investigators, representing several years of teaching experience, to assess students' academic background prior to enrolling in college as well as the kinds of experiences that they have had involving computers, mechanics, and automobiles. An example survey question is, "Have you ever installed software on a personal computer?"

Computer Attitudes Survey. The Computer Attitudes Survey measured students' attitudes towards computers and related technology. An example item from this survey is, "Computers make me feel uneasy." This survey was developed by combining items from other published questionnaires concerning attitudes toward technology.

Learning Styles. This online survey, developed by Felder & Soloman (2006), measures learning style preferences on four dimensions, namely, i) active vs. reflective, ii) sensing vs. intuitive, iii) visual vs. verbal, and iv) sequential vs. global. The survey includes 44 pairs of statements and students are asked to choose from each pair the statement that describes them the best.

Programming Knowledge (Pre- and Post- Test). Starting fall 2004, a programming language called Alice (www.alice.org) was introduced in EngE1024 to teach introductory concepts of object-oriented programming. The Alice programming environment uses the drag-and-drop method to develop a computer program and has a built-in collection of three-dimensional objects that are used to develop and run computer programs. The Alice programming environment allows the user to construct a simple to fairly complex computer programs that can be used to solve engineering or other real-world problems. Further, the user interface of the Alice programming environment is designed to make computer programming more accessible to people without a significant amount of programming experience. Another reason for adopting Alice was to bring “object-oriented programming” related content into EngE1024 course to partially satisfy the need of the Computer Science department that became part of the COE starting fall 2004. A programming concepts multiple choice test with 19 questions was adopted from the Alice collaborators to give a pre- and post-test measure for assessing the effectiveness of Alice instruction. In the fall 2005, this test went under revision and the final version included only 13 questions.

Focus Groups. Focus groups were conducted to gather feedback on specific aspects (e.g., hands-on activities) of the course.

Table 1 shows the period of data availability for various assessment tools implemented in EngE1024 course.

Procedure & Timeline

Fall 2004. At the beginning of the fall 2004 semester, first-year engineering students enrolled in the introductory engineering course, *Engineering Exploration EngE 1024*, were instructed to complete three surveys including the New Student Survey, Computer Attitudes

Survey, and the Learning Styles Survey on-line as part of a course assignment. The Web server of the Office of Academic Assessment hosted the New Student Survey and the Computer Attitudes Survey. Students completed the Learning Styles Survey online from a website devolved by the creators of the survey. After approximately 10 weeks of instruction, students completed the programming concepts pre-test in class. Students took the same test (i.e., the post-test) five weeks later after instruction concluded. Approximately 800 students participated in these surveys.

Spring 2005. At the beginning of the spring 2005 semester, students enrolled in EngE 1024 completed only¹ the New Student Survey and the Learning Styles Survey online as part of a course assignment. The procedure for administering the programming concept tests was the same as in the fall 2004 semester. During the last couple of weeks of the semester, two focus groups were conducted. This was the first time that focus group interviews were conducted to assess the learning outcomes in this course.

Fall 2005 & Spring 2006. The assessment procedures were identical to the spring 2005 semester except the programming pre- and post-test was modified as discussed prior.

General Findings from Assessment Measures

New Student Survey

The majority of the freshman engineering class is male (85%) and white (80%). In regards to prior background experiences, approximately 50% of the class has an engineer in the family and also has prior programming experience. In addition, the majority of students did not take any pre-engineering courses in high school. When asked to indicate all of the engineering majors they were interested in, many students selected mechanical engineering (53%), followed

¹Since there was little variance on the responses from the Computer Attitudes Survey this survey was eliminated. An example of an item with no variance is “Learning about computers is waste of time.”

by aerospace and ocean engineering (40%), electrical or computer engineering (37%) and civil or environmental engineering (33%).

Computer Attitudes Survey

The Computer Attitudes Survey was not administered after the first semester, because examination of the data revealed there was little variability in responses, which were mostly positive. First year engineering students were confident in their abilities to work with computers and other related technology. Additionally, they believed that learning about computers is valuable. Some examples of the questions are: “Knowing how to work with computers will increase my job opportunities.” “Learning about computers is worthwhile.” and “I will use computers in many ways in my life.”

Learning Styles

In regards to learning styles, the majority of the students are active, sensing, visual, and sequential learners (see Figure 1). However, reflective learners scored higher than active learners on the programming concepts post-test ($t(1627) = 4.59; p < .01$). Also, verbal learners scored higher than visual learners on the programming concepts post-test ($t(1627) = 2.91; p < .01$). There were also gender differences in learning styles. Specifically, women were more likely than men to be considered sensing ($\chi^2 = 7.10, p < .01$) and verbal ($\chi^2 = 6.84, p < .01$) learners.

Programming Concepts Test

During 2004-2005, Alice was introduced for the first time in EngE1024 and more emphasis was placed on learning Alice rather than OOP fundamentals. Based on students' feedback, significant changes were made in programming instruction during the 2005- 2006 academic year as the instruction focused more on learning programming concepts than on the specific program, Alice. Questions on the test were changed to reflect the modification in course

instruction. As such, the percentage of gain between the pre- and post-test scores was much higher for students in the 2005-2006 academic year (+26% gain) than students in the 2004 -2005 academic year (+12%).

Also, data analysis revealed that males performed significantly ($t(1671) = 4.87; p < .01$) better than females on the pre-test. However, there were no gender differences in post-test scores. Additionally, whites ($t(1438) = 4.02; p < .01$) scored higher than minorities on the post-test but not the pre-test.

Focus Groups

Responses from the focus groups provided feedback in regards to curriculum content.

Hands-on experiences. The students indicated that they would have preferred more hands-on experiences and projects in the class. Students said the current hand-on projects were nothing more than simply following instructions. They commented that they wanted more freedom and creativity in their hands-on projects.

Professional ethics. A variety of measures were employed to cover engineering ethics instruction in EngE 1024. Some examples are: assigned reading of engineering case studies and in-class discussion, in-class presentations on contemporary ethics related issues, and use of ethics video similar to “Incident at Morales.” Based on students’ responses during focus group sessions, they did not perceive a difference between personal and professional ethics. Nearly all of the students said that ethics couldn’t be taught in the classroom. They commented that by their age their morals were already formed. They also said that most people know when they are doing something wrong. When queried as to how the ethics instruction could be improved, the students suggested having debates on ambiguous cases and providing them with more legal information, specifically in regards to consequences of unethical behavior. A pre- and post-test for assessing

the effectiveness of ethics instruction has been designed as a result of these findings from focus group sessions.

Teamwork. Overall the students said they had a positive experience working in teams throughout the semester. Many students liked that their teams were chosen at random as this gave them the chance to meet new people. Additionally, many students said they did not learn anything new regarding working in teams. As with ethics, the students felt as though they had already learned everything about teamwork. More activities related to teamwork are being introduced in the course, and formal instruction to improve teamwork skills are also planned.

Predicting Engineering Success

For the purpose of this paper success in engineering program for fall 2004 cohort is defined using three factors: i) cumulative GPA after four semesters (i.e., spring 2006 semester), ii) course grade in the first engineering course (i.e., EngE 1024), and iii) engineering major retention. Retention in engineering program is interpreted as the retention in engineering program at the end of 4th semester (i.e., spring 2006) of a student. The data for the present study was analyzed using SPSS 11 for Mac OS X. Forced entry multiple regression analyses conducted followed the recommended procedure as described by Pedhauzer (1997).

Cumulative GPA

Regression analysis was performed to predict cumulative GPA at the end of 4th semester using SAT scores and course grade in EngE1024 as predictors. Together, SAT scores and course grade in EngE1024 (taken in fall 2004) explained approximately 55% of variance in cumulative GPA at the end of Spring 2006. That is, higher GPAs at the end of 4th semester were associated with higher SAT and course grades in EngE1024 in their 1st semester. Course grade alone accounted for 47% of the variance in GPA (see also Table 2). The introductory EngE 1024

course is a 2-credit course and the average number of credits completed at the end of the fourth semester is approximately 60 credits.

EngE 1024 Course Grade

Since course grade was a strong predictor of cumulative GPA, a series of regression analyses were conducted to explore what factors including prior experiences predicted course grade. First, factor analysis, using varimax rotation, was used to help identify related items and construct scales for the New Student Survey. Based on the observed patterns, four underlying scales were computed (by averaging responses across the items) from the New Student Survey items. Factor one ($\alpha = .76$) was comprised of items related to computer knowledge (e.g., *Do you know what open source software is?*). Factor two ($\alpha = .70$) contained items related to mechanical/automobile knowledge (e.g., *Have you worked on the engine or transmission of an automobile?*). Factor three ($\alpha = .72$) included items regarding engineering-related high school course work (e.g., *Did you take a mechanical drawing or drafting class during high school?*). Finally, factor four ($\alpha = .52$) was comprised of items related to time spent studying and reading (e.g., *How many hours a day did you spend studying?*).

First, regression models that included demographic variables, prior experiences, and learning preferences (see Table 3 for descriptive statistics) were tested. Gender and race (whites & minorities) were entered into block one, followed by learning style preferences (block two), and finally the New Student Survey factors (block three). Gender and race together were significant predictors of course grade. This prediction was primarily a function of race. White students performed better in the course than minorities. As a set the learning style variables were marginally significant predictors of course grade above and beyond race and gender. This was a function of the active – reflective dimension. Specifically, reflective learners had a significantly

higher course grade than active learners. Lastly, the four factors from the New Student Survey were also marginally significant predictors of course grade. The only New Student Factor to approach significance was the factor pertaining to computer knowledge. Taken together, gender, race, learning style preferences, and prior experiences as measured by the New Student Survey only explained five percent of the variance in course grade (see Table 4).

A second set of regression models were tested to examine how well programming knowledge and SAT scores predicted course grade. SAT scores were entered into block one followed by programming pre- and post-test scores. SAT scores were significant predictors of course grade. Programming scores also explained a significant amount of variance beyond SAT scores. This was primarily a function of post-test scores. Students with higher programming post-test scores were more likely to do better in the course than students with lower post-test scores. Taken together, SAT and programming scores explained approximately 24% of the variance in course grade (see Table 5).

Engineering Retention

Additional analyses were also conducted to examine what factors influenced engineering retention. That is, are there any specific background factors or prior collegiate experiences that relate to engineering retention rates? Again, for the purpose of this analysis a student is considered as “retained” in engineering if she/he was enrolled in the engineering program after the 4th semester of enrollment. Approximately 9% of the 1170 freshman students that completed EngE 1024 in the fall 2004 semester were no longer considered engineering major by the end of the spring 2006 semester. Due to small number of students who switched majors (approximately 100) and the significant amount of missing data on the New Student Survey, discriminate function analysis or logistics regression could not be conducted. Therefore, chi-square analyses

were conducted on many of the individual items on the New Student Survey that were hypothesized to influence retention.

The strongest background predictor of engineering retention after four semesters was experience repairing an electronic device other than a computer. Specifically, students who indicated in their New Student Survey that they had not repaired an electronic device other than a computer prior to college were more likely to dropout of the engineering program than students who had such experiences. Some prior experiences with computers also influenced retention rates. In particular, students who had no experience with DOS and did not know how to write computer programs were more likely to leave the engineering field than students who had worked with DOS and were able to write computer programs. Also, students who had worked with an engineer were less likely to drop out of engineering than students without such engineering related work experience. A list of the background variables that resulted in significant differences can be found in Table 6. There were also three quantitative variables that predicted engineering retention. SAT scores, programming post-test scores, and EngE 1024 course grades were significant predictors of retention. Specifically, students with higher SAT scores ($t(1128) = 2.84, p < .01$), programming post-test scores ($t(838) = 2.19, p < .01$) and EngE 1024 course grades ($t(952) = 4.85, p < .01$) were more likely than students with lower SAT scores, programming post-test scores, and course grades to still be an engineering major.

Conclusions

Course grade in the first engineering class was the strongest predictor of cumulative GPA for engineering students after four semesters. As can be recalled course grade explained nearly 50% of the variance in cumulative GPA four semesters later. The regression analyses pertaining to course grade suggested that background factors and learning styles have only a minimal

influence on success in an introductory engineering course. Programming post-test scores and SAT scores were much stronger predictors of course grade than any of the background or demographic variables. This information suggests that students can be successful in engineering despite a lack of prior relevant experiences (e.g., programming knowledge, engineering family member, developing a website, pre-engineering courses) before college.

The retention results reached a different conclusion regarding the influence of the background variables. Here, background experiences related to computers, mechanics, and prior course work (specifically math) did account for differences between students who decided to stay and leave engineering. In addition, quantitative variables also had a strong influence on engineering retention rates. Specifically, SAT scores, programming knowledge, and course grade in the introductory course all impacted student decisions to stay in the engineering domain. This paper highlighted some specific variables that influence success in undergraduate engineering programs. Knowledge of such variables can aid in intervention efforts.

References

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Table 1

Timetable of Assessment Measures for EngE 1024

	Fall 2004	Spring 2005	Fall 2005	Spring 2006
New Student Survey	*	*	*	*
Computer Attitudes Survey	*			
Learning Styles	*	*	*	*
Programming data	*	*	*	*
Focus Groups		*		*

Table 2

Summary of Variables Predicting Cumulative GPA after 4 Semesters.

Variable	Beta	Sig.	R-Square
Step 1			
SAT	0.004	0.870	0.080
Step 2			
Course Grade in EngE1024	0.741	0.000	0.552

n = 878

Table 3

Descriptive Statistics for Course Grade by Demographic Variables

Variable	n	Mean	S.D.
Gender			
Male	617	2.767	0.684
Female	115	2.872	0.591
Race			
White	447	2.858	0.655
Minority	84	2.664	0.652
Learning Preferences			
Active	569	2.701	0.730
Reflective	270	2.830	0.687

Note¹. Only demographic variables that resulted in significant differences are included in this table.

Note². Course grade was converted into a 4-point scale analogous to GPA.

Table 4

Summary of Demographic and Background Variables Predicting Course Grade.

Variable	Beta	Sig.	R-Square
Step 1			
Gender	0.06	0.29	
Race	0.13	0.01*	0.02
Step 2			
Active - Reflective	0.10	0.03*	
Sensing – Intuiting	0.03	0.57	
Visual – Verbal	0.02	0.61	
Sequential – Global	-0.04	0.40	0.03
Step 3			
Factor 1: Computer Knowledge	0.08	0.09	
Factor 2: Mechanical Knowledge	-0.07	0.15	
Factor 3: Prior Course Work	-0.07	0.15	
Factor 4: Time	-0.06	0.14	0.049

n = 443; * Statistically significant

Table 5

Summary of Quantitative Variables Predicting Course Grade.

Variable	Beta	Sig.	R-Square
Step 1			
SAT	0.359	.000*	0.202
Step 2			
Programming Pre-Test Score	0.053	0.162	
Programming Post-Test Score	0.194	.000*	0.243

n = 689; * Statistically significant

Table 6

Background Variables Influencing Retention

Variables from New Student Survey	Pearson Chi-Square	Sig.
Knowledge of writing computer programs	4.227	0.049
Repairing electronic device other than a computer	12.569	0.001
Replaced a fuse or reset a breaker	6.749	0.014
Worked on engine or transmission	4.813	0.031
Worked for an engineer	4.217	0.040
Math Level: Calculus I or higher	9.768	0.006

Note. Approximate sample size for variables is around 800.

Figure Caption

Figure One. Learning Style Preferences – Engineering Freshmen at Virginia Tech

