An Analysis of Freshman Engineering: A Cross-College Perspective

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Introduction

Virginia Tech's College of Engineering (COE) is the sixth largest US engineering program in terms of bachelor's degrees awarded in 2002[1]. All freshmen engineering students at Virginia Tech undergo a common first year General Engineering (GE) curriculum and are assigned to the Division of Engineering Fundamentals, which has recently been renamed as the Department of Engineering Education (ENGE). Students transfer from ENGE to eleven degree-granting departments as sophomores. The target enrollment in GE has been 1300 freshmen for the past decade, but this number will increase to about 1600 in the fall of 2004 due to the recent inclusion of the Computer Science Department in the College. With the addition of Computer Science, educational objectives of the common first year GE program have changed. Further, given the constantly increasing pressure to improve engineering education, the College must develop a more unified approach to improve the teaching and learning environment. Currently, the crucial linkages between the first year GE curriculum and the curricula in eleven degree-granting departments are not well defined. This can be attributed, primarily, to lack of coordination between faculty members in ENGE and the degree-granting departments. The new leadership of the COE has responded to these changes/ needs by re-conceptualizing and updating the mission of the ENGE department. The faculty in the Department of Engineering Education will now be responsible for improving engineering education and pedagogy within the College by undertaking scholarly activities in collaboration with their colleagues in other engineering departments and experts in education psychology and pedagogy. The three key issues that the College and ENGE must address are: i) the need for faculty and administrators to better understand the teaching and learning process so that they will be willing and enthusiastic partners in change, ii) the culture for assessment within COE is poorly developed and lacks an explicit focus on learning, and iii) the fact that the existing engineering curricula does not fully meet contemporary standards as suggested by several decades of progress in understanding student learning and development.

In September 2003, a group of ENGE faculty, aided by a number of engineering and education faculty, received a planning grant (project title: Bridges for Engineering Education-Virginia Tech (BEEVT)) under the Bridges for Engineering Education program of the NSF to create a contemporary framework for undergraduate engineering pedagogy. Additionally, the ENGE Department is currently in the process of hiring four new faculty members. Three new hires will develop communication related activities/assignments in engineering courses throughout the College and the fourth person will focus on educational assessment activities in the College. This paper discusses a number of initiatives that have been taken, and are being developed, to address the key issues assessment and of the reformulation of engineering curricula.

Assessment

In the fall of 2003, a number of engineering and education faculty members at Virginia Tech received a Bridges for Engineering Education planning grant from the NSF. The goal of this project is to initiate long-lasting collaborative relationships among Virginia Tech Engineering and Education faculty, K-12 educators, corporations, and policy/decision makers throughout Virginia in order to improve engineering education. The specific objectives are to: (i) develop a new Masters/Technology Education Teaching Licensure Option for engineering graduates; (ii) create a contemporary framework for undergraduate engineering pedagogy, beginning with freshman engineering experiences; and (iii) initiate the "Virginia Engineering /Education Collaborative" to ensure stakeholders' ownership of project outcomes.

A number of initiatives are currently underway to create the proposed contemporary curriculum framework. These initiatives can be classified into following categories:

- Collection and analysis of data
- Development of a continual assessment scheme
- Integration of GE curriculum with curricula in other engineering departments

In the following sections, a brief progress report of above activities is presented.

At Virginia Tech, students' retention, graduation, and intra-college migration data is maintained by the Institutional Research and Planning Analysis department online[2]. However, this information is not available in the form that can be readily used or interpreted. Therefore, this raw data was collected and processed to infer useful graduation and intra-college migration information. This information will be used as a tool in assessment. Based on analysis of 1994-1996 cohorts, it was found that:

- On average, 59% of students who enter Engineering have graduated from Virginia Tech's College of Engineering after 6 years.
- On average, 18% of students who enter Engineering have graduated from another college at Virginia Tech after 6 years.
- On average, 20% of students who enter Engineering are no longer enrolled at Virginia Tech after 6 years.
- The remaining 3% are still at Virginia Tech but have not graduated after six years.

It was also observed that about 53.6% students graduate from engineering programs within five years and only about 19.5% of the students graduate within four years of joining the program. The retention rates of different cohorts were compared with average SAT scores. Interestingly, it was found that while the average SAT scores went up during 1994-96, the corresponding graduation rates decreased (see Figure 1).

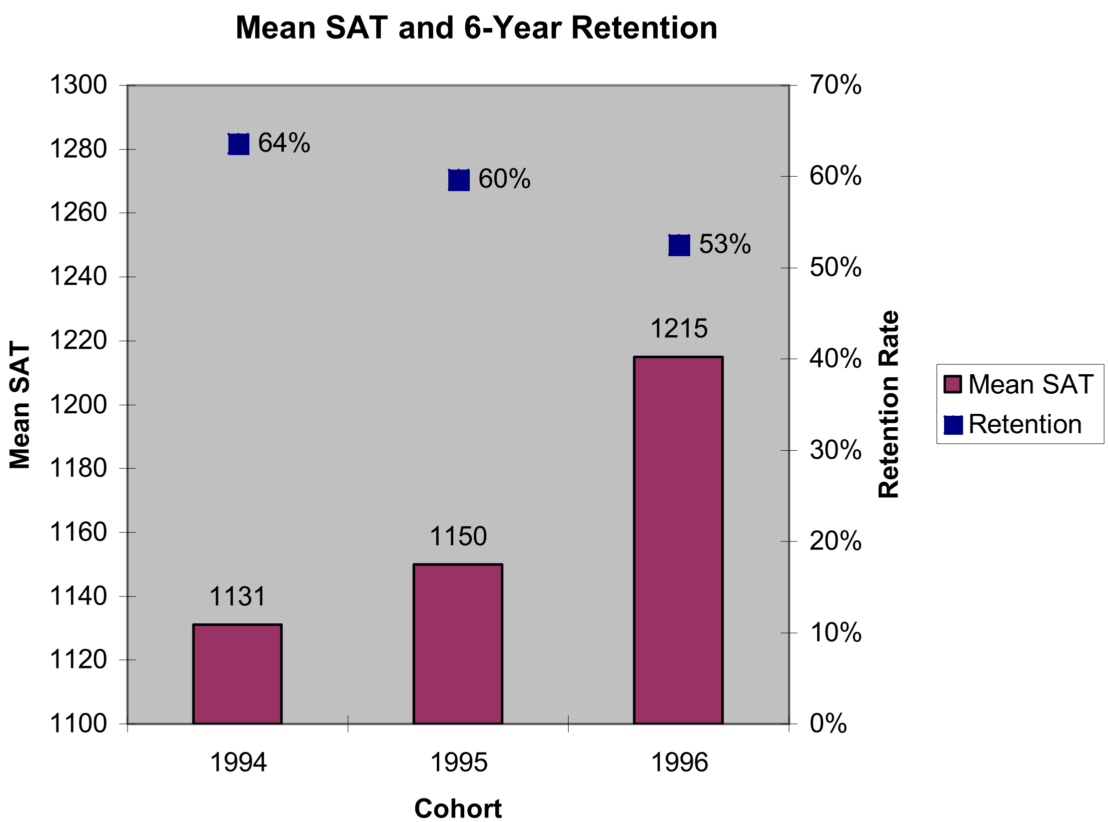


Figure 1 SAT and Retention

A major role of ENGE faculty is to teach and advise all first year GE students. The ENGE department offers two introductory engineering courses, namely, 'Engineering Exploration,' and 'Engineering Graphics.' In addition to introducing some fundamentals of engineering, these courses are designed to prepare GE students for their subsequent studies and are considered as the service courses in various engineering departments. The College of Engineering has 11 majors and these courses are expected to satisfy their diverse needs. This is obviously a challenging task for ENGE faculty. These courses, therefore, undergo frequent changes. A summary of topical changes in the 'Engineering Exploration' course is shown in Figure 2. The most obvious change is perhaps the dramatic decrease in theory and problems (i.e. traditional engineering topics such as statics and electricity) and a corresponding increase in design and hands-on activities.

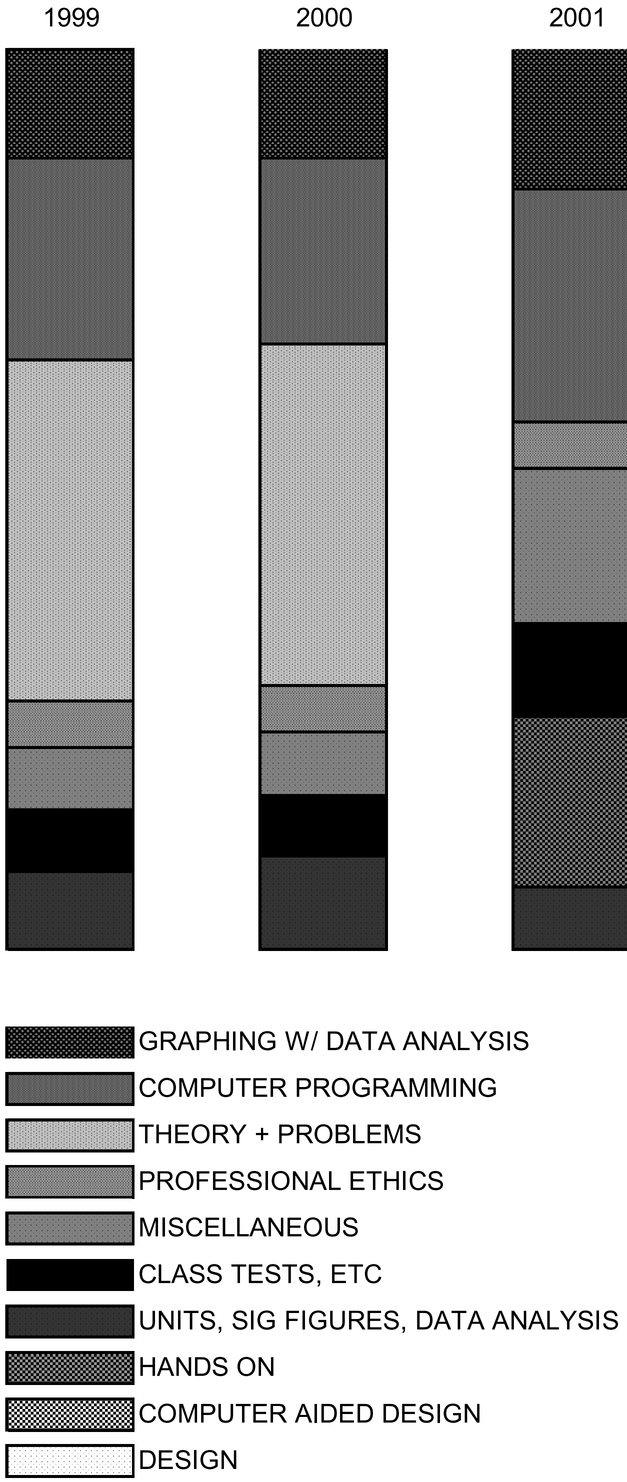


Figure 2: Changes in Freshman Year Engineering Course

In the past, due to lack of collaboration between faculty members in ENGE and other engineering departments, the ENGE courses were primarily designed by ENGE faculty. However, with the new mission of the ENGE department, it's important that ENGE faculty develop meaningful collaborative activities with their counterparts in various engineering departments. One of the areas of collaboration is in designing the GE courses. Traditionally this was accomplished in a sporadic, ad-hoc, manner that produced acceptable but certainly not optimal results. In order to streamline this process of designing ENGE courses the following initiatives have been taken.

In December of 2003 a questionnaire was sent to faculty representatives of various engineering departments asking what percent of time should be spent on various key topics during the freshman year. They were requested to assign each of the topics listed below a percent indicating the degree to which it should be covered such that the sum of all topics is 100%.

- Computer programming
- Written and oral communication
- Professional ethics
- Computer aided design
- Graphing with data analysis
- Design including project management and sketching
- The engineering profession and Tech's departments
- Engineering problem solving

Nineteen faculty representing all departments, including Computer Science, were requested to complete the survey and 12 responses were received representing 8 of the 11 degree granting departments. The average response for each topic is shown in Figure 3

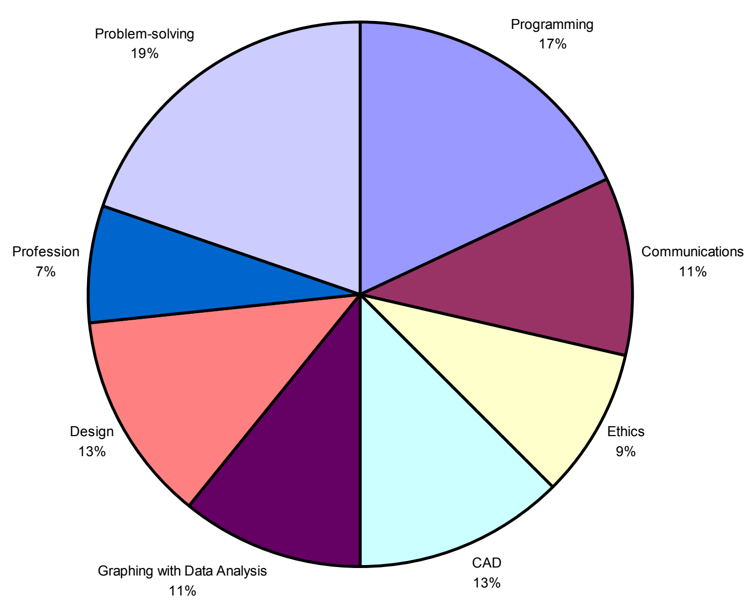


Figure 3 Initial Questionnaire Responses

Within each topic there was a wide range of opinion. As an example, the CAD topic responses are shown in Figure 4 (note that a few departments had multiple persons responding). Even within a given department there were wide discrepancies. An example is AOE (Aerospace and Ocean Engineering) where two faculty members wanted more than the average CAD coverage and the third faculty member wanting none at all. After collecting this information it became apparent that, in order to better serve the varying needs of eleven departments, a better feedback system was required that can be made available to departments online and store collected information for further processing. Therefore, a web based feedback system was designed for this purpose. The next section presents the current progress of this web-based system.

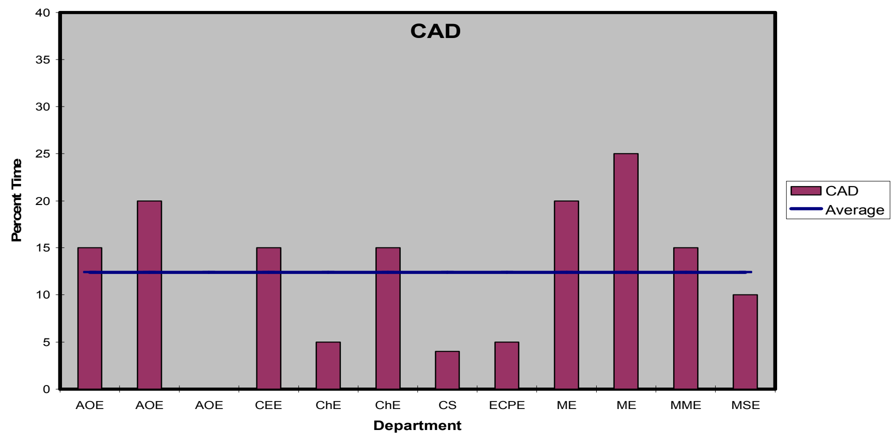


Figure 4 Example Responses, CAD

As part of our ongoing NSF planning project BEEVT, a web-based departmental feedback system has been developed. This system is targeted to better receive feedback from the degree-granting departments regarding the content of the first three semesters of engineering courses. This system allows the user to design freshman and first semester sophomore engineering content by choosing topics (programming, communications, ethics, CAD, graphing, design, profession, and problem solving) from an available set and allocate them to one of 42 weeks comprising the first year and a half of the students' education. Figure 5 shows an example of such feedback. In this example, the user has selected problem–solving to be taught two weeks in each of the first three semesters, the engineering profession to be covered during two weeks of the first two semesters, and so on. The center of the circle allows the user to input his/her expectations of an incoming freshman. While each of the three rings represents a semester, there is no time significance of the order of placement within a given ring; the software is designed to fill the rings, clockwise from north, with problem-solving first, profession second, etc. This is to facilitate visual comparisons.

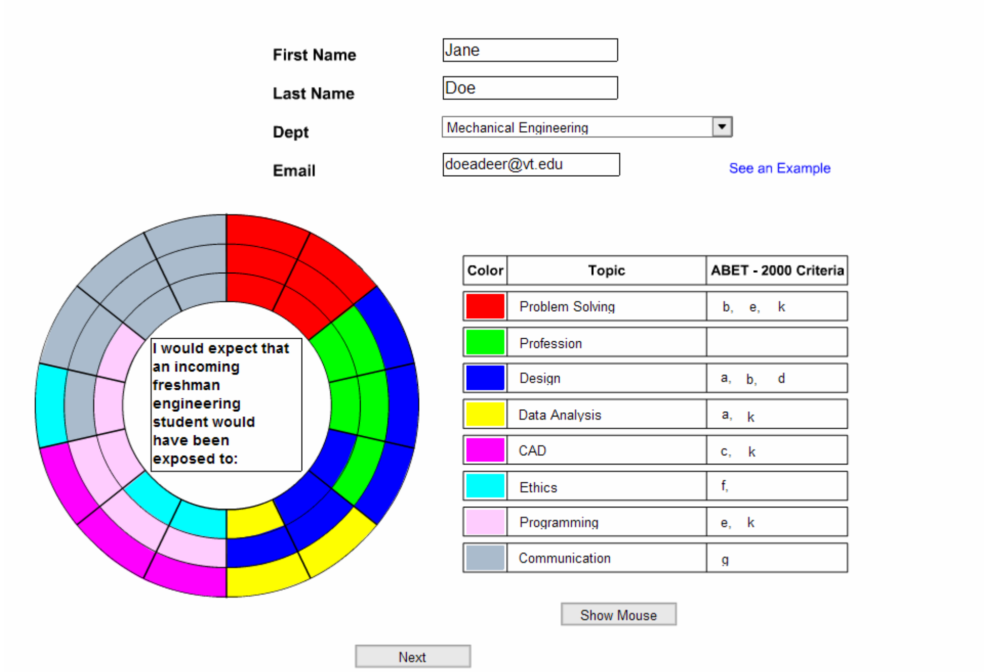
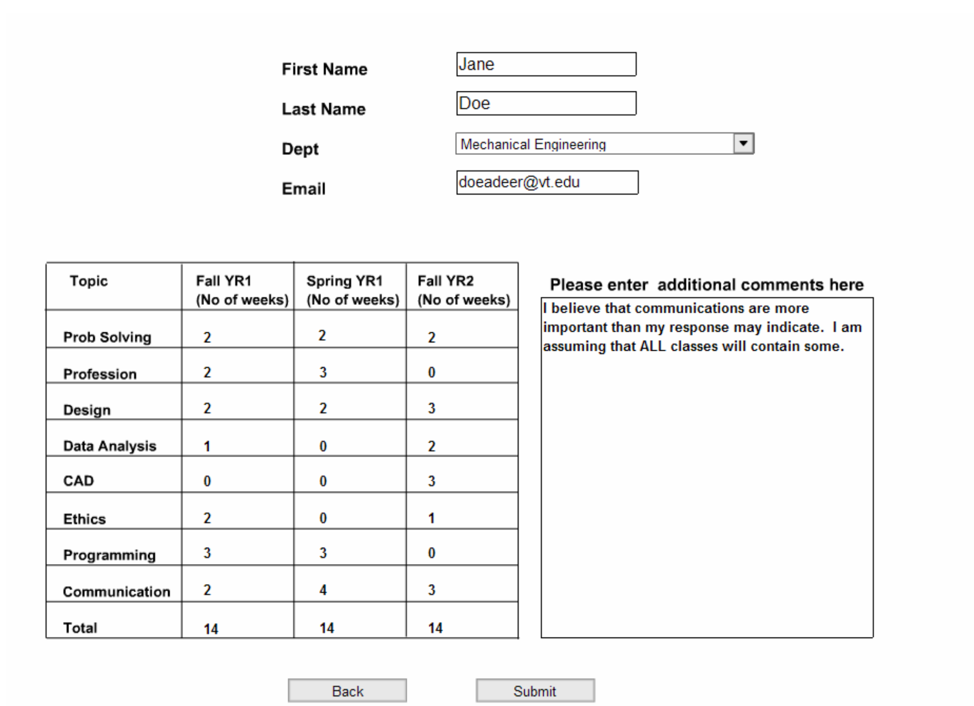


Figure 5 Web-Based Departmental Feedback System

When the user has completed the graphical portion a summary page, the visual information is automatically translated into quantitative information in a tabular form (see Figure 6) and allows the user to go back and make comments before submitting. Once submitted the input data is stored and readily available for statistical analysis and re-creation of the graphical input.



First Name: Jane

Last Name: Doe

Dept: Mechanical Engineering

Email: doeadeer@vt.edu

Topic	Fall YR1 (No of weeks)	Spring YR1 (No of weeks)	Fall YR2 (No of weeks)
Prob Solving	2	2	2
Profession	2	3	0
Design	2	2	3
Data Analysis	1	0	2
CAD	0	0	3
Ethics	2	0	1
Programming	3	3	0
Communication	2	4	3
Total	14	14	14

Please enter additional comments here

I believe that communications are more important than my response may indicate. I am assuming that ALL classes will contain some.

Back Submit

Figure 6: Quantitative feedback from Users

Assessment of student learning outcomes is a major concern for any innovative curriculum reformulation strategy. Assessment is an ongoing process aimed at understanding and improving learning. As part of ongoing BEEVT activities a comprehensive approach for undertaking program assessment and in-class assessment of instruction has been planned. A brief description follows.

All engineering students at COE are required to own a laptop with a wireless Internet access. McGourty[3] discussed the application and results of a computer-based survey called Team Developer for assessing student learning outcomes linked to the ABET2000 in several programs, including New Jersey Institute of Technology, Ohio State University, and University of Pittsburg. As a part of BEEVT activities, we propose to examine application of this tool in our program. Alternatively, we are also considering developing our own software for collection and storage of team member evaluations electronically. Students involved in group work will be asked to use this online system to rate their team partners using different categories. This will allow students to track their team performance as rated by peers over the course of a semester and from semester to semester. Currently, students turn in hard copies of peer evaluations to instructors in ENGE courses. An electronic database of peer evaluations will let us examine a number of issues related to teamwork evaluation. For example, team composition as related to its effectiveness, role of team skills in overall academic performance, curriculum changes as related to team skills development, etc. The proposed team builder tool may ultimately become part of an existing online course management system called Blackboard or Virginia Tech Electronic Portfolio system (i.e., e-Portfolio).

Minute papers are used to get students' feedback on instruction. Since all engineering students are required to own a laptop with wireless card we propose to develop a system for collection and storage of minute papers electronically. This system will allow us to develop a valuable database on students' observations in various engineering courses. Such a database will not only help current instructors in improving instruction but also will also be a valuable teaching tool for new instructors at the College of Engineering and elsewhere.

In a traditional setting, assessment activities in the capstone course have served as a convenient mechanism to accomplish the comprehensive assessment of student learning in a program. While a useful tool, one drawback is a necessarily limited range of activities measured in a single project. In order to develop a continual assessment scheme, a comprehensive tool that can be accessed easily and can store and retrieve information is required. One such tool is the electronic portfolio. A group of faculty at Virginia Tech began working with electronic portfolios during the summer of 2003 using the open-source software developed by the University of Minnesota for this purpose. This multi-institutional pilot project has continued throughout the 2003-04 academic year with faculty using e-portfolios in their classes. A sub-set of BEEVT investigators (including Knott, Lohani) participated in this pilot. The e-portfolio is being evaluated as a tool for improving student learning and improving communication skills and as a tool for assessment[4]. The infrastructure for e-portfolios is in place and is operational at Virginia Tech and its potential for collecting assessment data will be evaluated in coming months.

Reformulation of Engineering Curricula

In past, systematic efforts to better define crucial linkages between GE curriculum and the curricula in engineering departments have not been made. The proposed activities in the BEEVT project aim to undertake such collaborative activities and the ENGE faculty members have already taken some initiatives in this direction in recent months. As an example, six ENGE faculty in collaboration with seven faculty members in Biological Systems Engineering (BSE) department developed a proposal to undertake department-level reform of the GE curriculum along with the Bioprocess Engineering curriculum in BSE department. This proposal is under consideration at the NSF. This proposal represents an unprecedented level of collaboration between two engineering departments at the College of Engineering and involves active collaboration with experts in educational psychology and academic assessment. The Bioprocess Engineering option within BSE was selected because it is a relatively new program in the emerging field of biotechnology. . Since the creation of the Bioprocess Engineering option about five years ago, the student enrollment in this option has increased in size from about 5 students to 20 students and it is expected that enrollment will double within the next few years. This rapid growth has provided the faculty with new educational challenges and a perfect opportunity to collaborate with the ENGE faculty to work on curriculum reforms.

The proposed reforms include adopting the concept of spiral curriculum for linking GE curriculum with the Bioprocess Engineering curriculum. The twentieth century psychologist, Jerome Bruner, proposed the concept of the spiral curriculum in his classic work *The Process of Education*[5]. Bruner advocates that a curriculum as it develops should revisit the basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them. Further, he proposes structuring a curriculum around the great issues, principles, and values that a society deems worthy of the continual concern to its members. Bruner's theory on spiral curriculum has been adopted for reformulating diverse academic curricula. For example, Wark and Kohen[6] describe using a spiral curriculum approach for redesigning a hypnosis training program at University of Minnesota. Elizondo et al[7] discuss use of the spiral approach in horizontal and longitudinal integration of Basic and Clinical Sciences in a medical school curriculum reform in Mexico. The concept of core curriculum in medical education in the U.K., presented by Harden and Davis[8], uses spiral curriculum approach as one of its underlying philosophies. Results of a successful project-based spiral curriculum design, implementation, and evaluation in chemical engineering curriculum at Worcester Polytechnic Institute, MA are presented in a series of papers by Clark et al.[9], Dixon et al.[10], and DiBiasio et al.[11]. The authors claim that spiral-taught students displayed equal or better understanding of basic chemical engineering principles, performed better in upper level courses, and had higher satisfaction levels with their academic experience as compared to traditionally taught students who followed instruction in a compartmentalized sequence of courses.

In the proposed GE – BSE curricula reformulation, a theme of sustainability has been selected to provide a contextual framework. The supporting principles of design, ethics, and a systems approach and cross-cutting skills of communication, teamwork, life-long learning, research experience, and lab experience will be woven throughout the curricula. In the reformulated GE and Bioprocess Engineering curricula, students will apply the supporting principles of engineering (design, ethics, systems approach, etc.) to problems related to sustainability. During the freshmen year in GE program, theme related problems will be dealt with on a lower level or using simulation models like the Alice system[12] and laboratory exercises that do not require upper level curriculum knowledge. As the student progresses through the curriculum, the same and new sustainability problems will be addressed with increasing sophistication using more recently acquired skills and knowledge from engineering and other courses. Successful implementation of this proposal will be used as a model for incorporating similar reforms in other engineering departments in the College and elsewhere.

Summary

A number of teaching/learning initiatives have been undertaken by Virginia Tech's Department of Engineering Education faculty as part of a National Science Foundation Bridges for Engineering Education grant. A novel, web based, tool has been developed that allows faculty in other departments to provide their perspective on the General Engineering program. Classroom and program assessment is being improved through the use of e-portfolios, minute papers, and team developer software. Pedagogy improvement and the integration of the GE program with the Bioprocess program is being accomplished through the use of a theme based spiral curriculum. It is expected that this integration will be accomplished over the next few years and will serve as a model for other engineering departments both at Virginia Tech and nationwide.

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Biographies

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