AC 2010-654: ENGINEERING EDUCATION IN CONTEXT: AN EVIDENCE-BASED INTERVENTION SYSTEM

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Engineering Education in Context: An Evidence-Based Intervention System

Abstract

An evidence-based intervention system is proposed to provide for guided evolution of engineering education programs. Too often, innovative designs for educational enhancement fall into disrepair because they embodied the unintended consequence of built-in obsolescence. The ineffectiveness of many designs has been resident in a static view of learning and teaching styles, personnel-dependence, an inability to manage changes in program size, and/or a lack of portability and adoption by the larger educational community. To avoid these specific pitfalls in our design for educational enhancement, we are: (1) employing a dynamic view of learning and teaching styles where the characteristics of student and faculty are periodically measured to establish an assessment process calibration, (2) using knowledge management systems to process voluminous data collection and analysis in an efficient and flexible manner, (3) using a modular design of an established assessment paradigm that provides points of real-time intervention to responsively optimize educational practices, and (4) using a widely-practiced assessment paradigm that confers transferability of the process with its value-added, best-practices modifications to other educational systems. The approach to accomplish these goals is based upon decision support software currently in use in business and health care. The implementation of Instructional Decision Support System (IDSS) approaches will provide rapid feedback of assessment data combined with student characteristics to empower faculty instructors and enhance student learning.

Preliminary data has provided a basic proof-of-concept for the IDSS approach. Data from the Index of Learning Styles indicated that the students surveyed were sequential, as opposed to global, learners. Instructors found that redesigning some courses to provide a more sequential, step-by-step style enhanced the student experience in selected courses. Other data showed that students surveyed were not as positively inclined towards engineering as might be expected for a biomedical engineering program. If confirmed, this data can be used to provide support for developing new educational experiences targeted to improve students' attitudes towards the discipline.

Introduction

The National Science Board has emphasized that "engineering education must change in light of the changing workforce demographics and needs"[23]. We face unprecedented global pressures and an ever increasing diversity in the US population. To meet the challenges of the 21st century engineering in such a competitive environment, the United States must produce the best, most adaptable and highly trained engineers possible. It is the job of engineering programs in higher education to adapt to new conditions in order to develop these innovative 21st century engineers.

In this work, the potential of a web-based knowledge management system that promotes personalized learning is investigated. The system focuses on student learning by delivering real-time information to faculty, administrators, students, and alumni to enhance curriculum development and streamline accreditation processes. The platform utilized in this investigation, the Academic Evaluation, Feedback and Intervention System (AEFIS) – from Untra Corporation, provides systemic support and knowledge management allowing for the development of an Instructional Decision Support System (IDSS). The IDSS is designed to ensure that the engineering education system co-evolves appropriately with student characteristics and the needs of the global community. The present implementation of the system, as well as current studies to determine proof-of-concept, are described.

The problems faced by modern engineering educators have much in common with the difficulties experiences by physicians and for very similar reasons. In the past, the family doctor treated the same patients for many years, often working with families over generations. This intensive interaction built up a significant knowledge base, allowing physicians to detect subtle differences in patient health and behavior and an understanding of which therapies would, and would not, work for specific individuals. In the modern health care system, this intimate relationship between physician and patient has been broken, as physicians see more and more patients for ever decreasing amounts of time. Combined with the sheer volume of medical data available, physicians no longer have the ability to obtain sufficient knowledge to develop the best therapies for each individual patient. Knowledge management systems in the form of Clinical Decision Support Systems have been designed to bridge this gap by distilling significant amounts of medical and patient data into an accessible and useable format.

Similarly, a close mentor-student relationship, developed over extended periods of time, is perhaps the best way to facilitate student learning. This is why such approaches are still prevalent in medical education after medical school and in graduate programs. However, the modern engineering faculty faced with large classrooms and brief educational experiences bracketed into 15-week semesters or 10-week quarters cannot get to know each student well enough to facilitate a personalized mentoring approach. In addition, the various draws on faculty time for research and scholarly activity makes it difficult to spend the necessary time to create the best learning environment. What Clinical Decision Support Systems are attempting to do for physicians, we believe Instructional Decision Support Systems can do for educators. For this to be practical, two things are needed. First, some form of effective characterization of students that facilitates the learning process and informs faculty instructors is required. Second, a method of providing access to innovative instructional techniques in an accessible and useable format would allow instructors to select the most appropriate instructional methodologies to match their specific classes.

As difficult as it is to characterize students in a manner that assists in designing educational paradigms, there is good solid evidence from numerous sources that such characterizations can be obtained and successfully applied to improve student learning[3,4,6,7,9,10,11,12,13,15,17,21,22,26,27]. Why then have these approaches not achieved widespread application in engineering education? Why are there not already IDSS approaches being used in practice? We believe there are several key reasons for this limited implementation.

1. **Limited measurements -** Characterization of the instructional system has been limited to only a few variables measured simultaneously. Some studies measure learning styles, others motivation, some teaching styles, others aspects of curricular organization but none to date

have measured all these variables simultaneously[3,6,7,8,11,13,18,20,22,24,28]. In effect, neither student characteristics nor curriculum design have been adequately examined. Our current approach involves measuring multiple parameters on students, instructors and curricular design to overcome this limitation as well as investigate interactions between the various parameters.

2. **Focus on results before process -** Previous studies focused primarily on results rather than process. Thus, it has been difficult to determine the extent to which these data were generally applicable, and no systematic method is available for determining if the data were replicable to new programs, students, institutions and/or situations. In contrast, this proposal concentrates heavily on the development of processes that integrate instructional (student, instructor, course, curriculum) measurements and analysis with ABET (Accreditation Board for Engineering and Technology)-mandated assessment and improvement. Thus, a major deliverable of the project is a transferable system with which other engineering programs could monitor their own instructional environment and develop and test their own educational innovations.

3. **Ease of use -** A key trade-off in the utility of any innovation is the time and resources needed to implement it versus the benefits that result from the implementation (in this case, improved student learning). Since prior studies focused on results and not processes, the cost/benefit assessments for implementing a system to make use of the studies' conclusions were not considered. Such analysis is inherent in the present studies with methods for systematic implementation a key element of this project. The end result is expected to be a systems approach that can be implemented in any engineering program with any student body.

Critical Role of Information Technology and Systems

Why were the results from previous studies not better utilized? It certainly appears that more programs could have used this data to create new instructional paradigms than has actually been the case. We believe that the problem is not so much in the lack of knowledge but rather in inadequate knowledge management (KM). The integration of student, instructor and course/curriculum characteristics into a sustainable system for continuous educational quality improvement is fundamentally a knowledge management issue. The information system being developed by this project represents a proof-of-concept implementation which demonstrates the feasibility of continuously measuring the instructional environment which can compliment innovative new approaches to teaching and learning.

Objective

Develop and implement customized information systems for the collection, analysis and use of key participant and educational material characteristics. Specifically:

1. To develop and implement an information system for the collection and analysis of student and faculty instructors characteristics;

2. To develop and implement an information system for the collection and analysis of course and curricular characteristics;
3. To develop and implement an information system for the collection and analysis of student performance;
4. Develop and implement a method for instructional support that ensures these data are used to ***enhance student learning***.

The Information Systems Approach

The key factor in any continuous quality improvement approach is to ensure that the data collected is actually used effectively. In the language of accreditation, this is often described as 'closing the loop' and is the 4th goal listed above. As the front-line deliverers of instruction, the enthusiastic collaboration of the faculty is necessary for the implementation of changes based upon assessment data. However, faculty are not always eager to embrace assessment and any attempt to institute large or radical changes in the behavior of faculty instructors can run into considerable resistance. Recognizing that the ultimate goal of any academic system is the improvement of student learning, we focused on what could be done to support faculty instructors in making decisions about teaching methods and approaches in the engineering curriculum. Curriculum design and assessment is embedded in the process. If successful, accreditation becomes a byproduct of a successful curriculum, rather than an overt goal. This led to the development of a new idea - the Instructional Decision Support System or IDSS.

Decision Support Systems (DSS) can be defined as a class of information systems that augments organizational decision-making activities. A well-designed DSS is often implemented as an interactive software package that allows decision makers to compile relevant information from raw data, prior activities/results, documents, personal knowledge and/or models to recognize problems and provide potential solutions[22]. According to Dr. Robert Hayward of the Centre for Health Evidence, in medical practice, clinical decision support systems (CDSS) "link health observations with health knowledge to influence health choices by clinicians for improved health care"[29].

We define our Instructional Decision Support System as an ***interactive computer-based information system which links student characteristics, student performance, instructor characteristics, learning outcomes, and instructional methods to inform faculty decisions on the appropriate educational pedagogy to improve student learning***. This is an adaptive system that continually processes real-time data to constantly adjust the information being presented to the faculty instructor.

Current Implementation

The knowledge management (KM) system in use in our approach is in the final stages of development. The AEFIS Pilot Program has provided student and faculty feedback for the solution's continued growth. Many of its components are already designed and implemented while those related to the IDSS approach are in the preliminary testing stages. Those components that have been designed and implemented include:

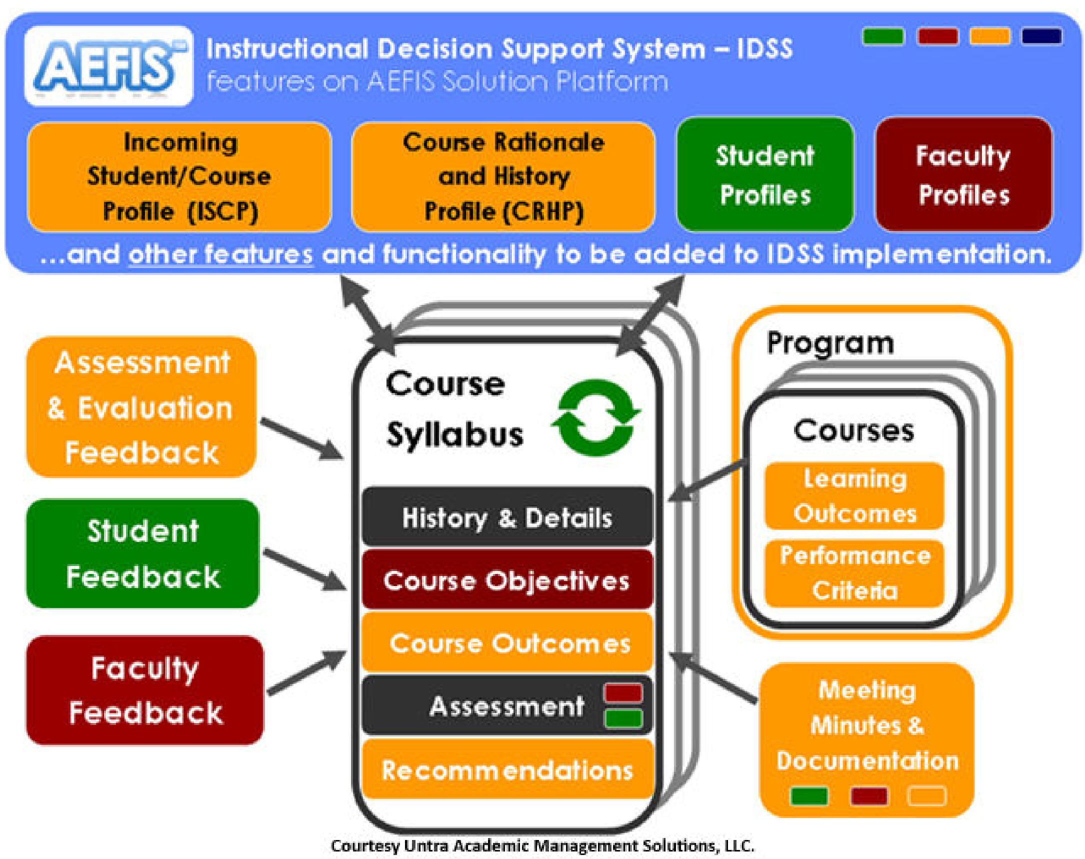
1. Course Syllabus Management
2. Survey Management
3. Student Learning Outcomes (SLOs), Performance Criteria (PCs) and Rubrics Management
4. Academic Program Design and Development Management
5. Direct & Embedded Assessment Measures Management
6. Meeting Minutes and Accreditation Document Management

The relevant characteristics of each component are briefly described below.

The **AEFIS Core System** incorporates a Web based portal for all assessment activity by all user groups. Within the portal, there are user specific dashboards for action items and access to system functions. Integration with academic management systems is provided through automated data import, validation and processing.

Course Syllabus Management
The function of this component is to manage and administer course syllabi. This tool set provides centralized access to all course syllabi, notes, recommendations, course outcomes or objectives, program-level SLOs and PCs that are mapped to each course, the syllabus approval process and other pertinent matters.

Figure 1*: AEFIS Syllabus Management Approach and conceptual view.*



The syllabus lies at the heart of this approach and allows everything to be connected to form meaningful associations between key system data. Ultimately, the syllabus allows for an "aggregate view" and forms a conceptual meeting point for a variety of assessment, evaluation and course data in a single location.

Survey Management

Using this component, users can create and manage ad-hoc as well as repeating surveys for a variety of purposes, including functionality to support survey scheduling, survey invitation/reminder email messaging, and survey rewards management. Survey design, development, approval process, reporting, active/inactive status, and history are all available. Typical surveys in current use include Student Course Evaluations, Student Personality Surveys, Faculty Course Evaluations, Faculty Personality Surveys, Class Exams, Random Research Surveys, Senior Exit Surveys, Alumni Surveys, and Employer Surveys. Thus, this is the component that collects among other data, student and faculty instructor characteristics.

Student Learning Outcomes (SLOs), Performance Criteria (PCs) and Rubrics Management

This component allows users to create and manage Student Learning Outcomes (SLOs), related Performance Criteria (PCs) and their associated rubrics. A user has the ability to manage entire lifecycles of these information pieces in the system with design, development, approval process, collaboration, versioning and history all available. With this component, the programmed student learning outcomes and associated performance criteria are developed.

Academic Program Design and Development Management

This component allows users to create and manage academic programs and curriculum using innovative approach by way of mapping courses, outcomes and performance criteria together in varying levels from University Level to Unit/College Level to Program Level while being able to allow inheritance of these outcomes from the higher level(s). As with the previous tool set, the user has access to the design, development, approval process, versioning, and history of all aspects of the mapping process. By mapping SLOs and PCs into the curriculum, users can design a developmental appropriate learning experience for each SLO/PC.

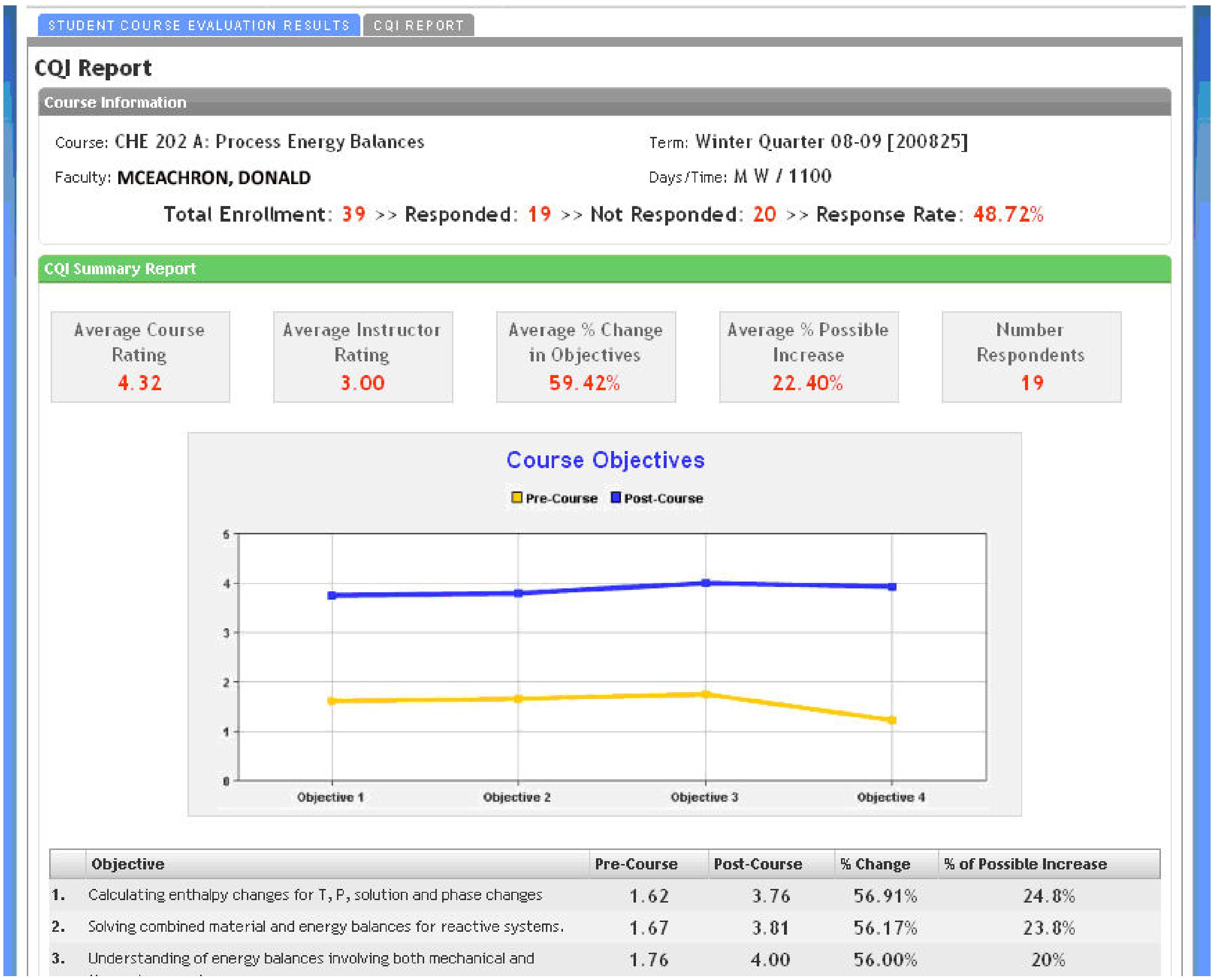
Direct and Embedded Assessment Measures Management

Using this tool set, users can create and manage Student Learning Outcomes (SLOs) based on Performance Criteria (PCs) centered direct assessment measures and embed them into the curriculum. Similar to the above, the user has access to the design, development, reporting, versioning, and history of all aspects of the process. This is where users gather data on actual student performance on SLOs and PCs. These are the dependent variables against which other factors – student/instructor characteristics, educational methodologies, etc. – are measured.

Meeting Minutes and Accreditation Document Management

This component allows users – typically administrators – to create and manage meeting minutes and maintain an accessible document repository for assessment and accreditation information.

__Figure 2__: Results from the current Student Course Evaluation for showing students' responses to their knowledge of Course SLOs (Course Objectives) BEFORE and AFTER the course and the difference between the two provides us with an "Indirect & Non-Evidence Based" measure of how much students learned in the given course.



Data Overload and the IDSS Concept

The current implementation does an excellent job of collecting and managing data, doing this job almost too well. The amount of data being collected is enormous and the very quantity of information available can be inhibiting to effective use of that data by individual faculty. To overcome this problem, we are currently developing three standard reports to be presented to each faculty instructor prior to the beginning of any term in which that instructor is teaching. These serve as the starting point for decision support. The reports provide the most relevant data collected to date in a brief and easy-to-read format to provide the most effective delivery of useful information. The three are:

1. **Incoming Student/Course Profile (ISCP) –** provides information on student characteristics, such as learning style, intelligence type, personality type, etc. that have been shown relevant to student learning. Performance criteria to be covered in the course are emphasized and suggestions for best practices in teaching these types of students these specific performance or learning outcomes are given. Embedded links provide access to specific teaching methodologies.

2. **Course Rationale and History Profile (CRHP) –** shows how each course fits into the curriculum, not only highlighting pre-requisite and following courses, but also the expected developmental stage of learning that students are expected to have entering the course and attain upon completing course materials. The association of learning outcomes and class assignments for previous class offerings are provided. Summaries of faculty and student comments on the success or failure of different teaching approaches can be accessed through specific embedded links.

3. **Evaluation Results Notes and Recommendation (ERNR) –** This form provides a summary of student and faculty course evaluations (which is linked to the Course Rationale and History Profile), trend analysis of student performance over several iterations of the course, a historical listing of recommendations for improvement and the measured effects of those recommendations when implemented.

These reports do not prevent instructional faculty from engaging in more complete data investigation and analysis should they choose to do so. Indeed, further development is planned for additional investigative tools such as **Integrated Electronic Portfolio Management** tool set which will support an integrated evidence-based assessment of student ePortfolios as well as other management tools and an **Advanced Analysis and Reporting Tool Set** for statistical trend analysis, custom reports, data export, and document handling. However, given the myriad demands on faculty time, the IDSS must provide a useful data 'snapshot' to facilitate making instructional decisions without requiring significant additional effort. We believe these reports will serve that purpose while ensuring that assessment data is continually utilized.

Current Studies

In order to gauge the potential of the proposed system initial studies have been performed with Drexel University students serving as the test-case. Students majoring in biomedical engineering at the School of Biomedical Engineering, Science and Health Systems at Drexel University participate in a core curriculum as well as specializing in at least one of five concentration areas – Biomaterials and Tissue Engineering; Biomechanics and Human Performance Engineering; Biomedical Devices and Imaging; Biomedical Informatics; and Neuroengineering. The freshman year is very similar to that taken by all engineering majors at Drexel, the sole differences being a seminar course in the Fall Term introducing biomedical engineering and a course in cells, molecular biology, and tissues taken in the spring term. Sophomores share numerous courses with other engineering students but also participate in a specialty course investigating prosthetic design and two terms of human physiology. As pre-juniors, biomedical engineering students take a core set of courses and laboratories including a course on biosimulation and a team-taught, project-based sequence introducing the five concentration areas. At the end of the pre-junior year, all students must choose a concentration area in which to specialize and participate in an examination testing their knowledge of basic science, mathematics and engineering principles. During the junior year, students take courses in the concentration area as well as a two-course sequence reinforcing the techniques of engineering design and project management. During the senior year, students participate in two capstone experiences: a senior sequence of 2 or 3 courses in their concentration area and a senior design project.

We are currently collecting data on student and faculty characteristics with the intent of correlating the following independent variables with the dependent variables of program (student learning) outcomes, specifically the achievement of the ABET established performance criteria.

Independent Variables

Independent variables are student and faculty characteristics that may affect learning outcomes. We use several well established and some newly researched instruments to identify the key characteristics that may correlate best with student learning.

Student data is being collected initially at three points in the curriculum: (1) during the freshman year, (2) during the pre-junior year and (3) during the final quarter of their senior year. The battery of tests includes the Inventory of Learning Styles[9,11,20], the Myers-Briggs Personality Inventory[12,25] the Student Developmental Task and Lifestyle Inventory[30], a Multiple Intelligence Inventory[1,2,5,14,21,22], and a perspectives and motivation inventory recently developed by Li and colleagues[19]. Additional data on workload and scheduling is also being collected.

Faculty instructors submit surveys related to teaching styles, goals and perspectives. We also hope to soon collect faculty data on the Myer-Briggs Personality Inventory, the Multiple Intelligence Inventory and Li et al.'s perspective inventory as well.

Dependent Variables

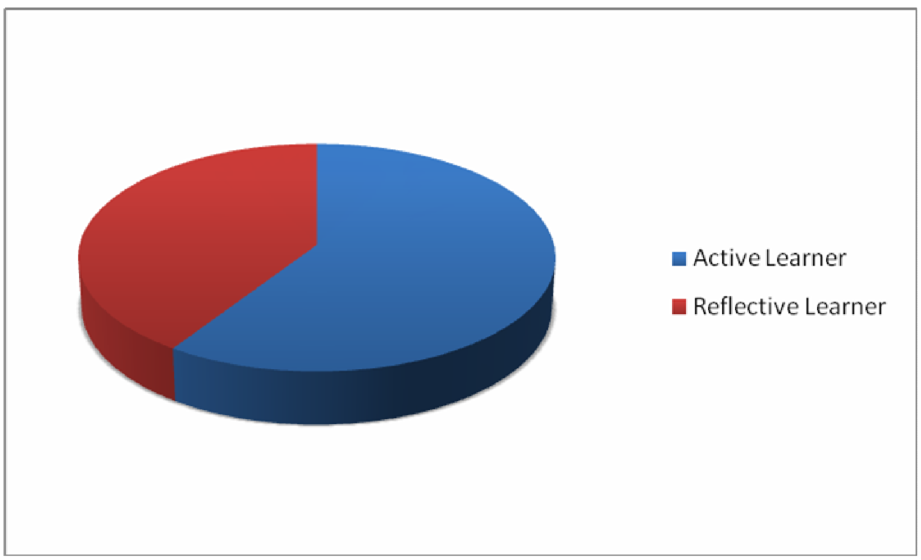
The main dependent variables are the program's performance criteria. Performance criteria relate to student learning outcomes which, in turn, support the program's objectives. We use the ABET definition of learning outcomes as being attributes and levels of knowledge and skills demonstrable by students upon graduation from an engineering program and program objectives as characteristics or attributes displayed by graduates of the program three and five years post-graduation. Each learning outcome is subdivided into a number of performance criteria. Each performance criterion is associated with a number of achievement levels. Each achievement level is described so that a student's level of success in attaining each criterion can be measured in any given instance, for a particular paper, oral presentation, or team project. In the ABET terminology, the achievement levels with their associated descriptions are called ***rubrics*** although metrics might be a more appropriate term. Rubrics measure the level of learning, primarily based upon Bloom's taxonomy[1,2,14], for each performance criterion. Currently, the biomedical engineering program has 14 learning outcomes common to all concentration areas subdivided into 60 performance criteria. Each concentration has an additional unique outcome assigned to it with 3-5 associated performance criteria.

Preliminary Results and a Proof-of-Concept

As of this time, we have collected data on some 100 freshmen, pre-junior and senior students. The numbers vary slightly insofar as different numbers of students completed each survey. Data collection on faculty is set to begin in January, 2010.

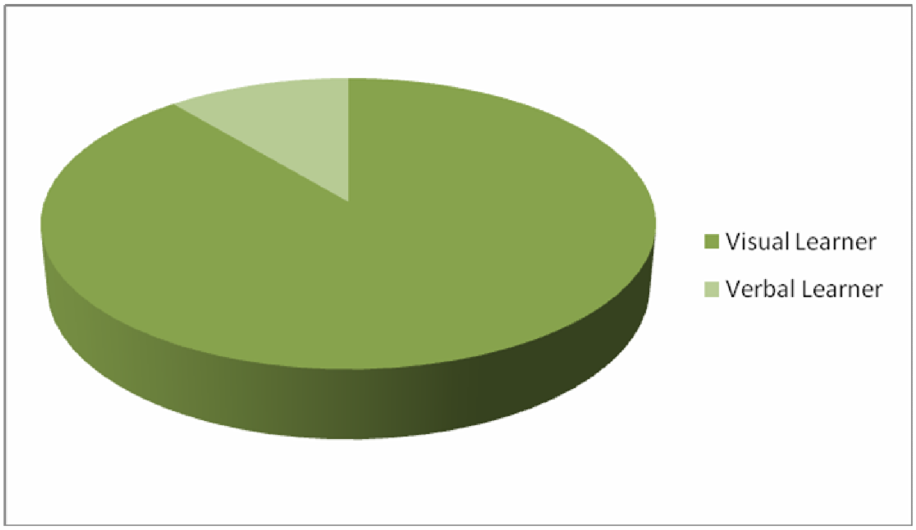
In analyzing the survey data collected from participating students, the data were initially sorted by academic level or class and by gender. Thus, we are able to continuously obtain valuable insight into the student body's personality and characteristics as a whole, within particular demographics, for an individual class or course, and on an individual student basis providing the ability to precisely modify teaching methodologies to best fit the student body and maximize learning outcomes.

***Figure 3**: Relative proportions of Active and Reflective Learners among Current Biomedical Engineering Students at Drexel (**Active** learners prefer to learn through engaging in a physical activity or discussion while **reflective** learners are more comfortable using introspective techniques[11])*



Initial results from the proof-of concept trials have begun to provide insight into the depth of information available from these suggested practices. Data from the Myers-Briggs showed that as the students progress through the program, they become more satisfied with how and what they are learning. An approximate rating of 1.75 satisfaction for freshmen develops into approximately 3.0 for upperclassmen on a scale 1 to 4. The Engineering Perspectives survey[19] showed that the perceptions of the difficulty of engineering vary within gender and class. On a scale of 1 to 7 (7 being the most difficult) freshmen women perceived engineering as markedly more difficult than their male counterparts by a score of 5.99 to 5.35 respectively. By pre-junior year the values are higher and women still perceive engineering as being slightly more difficult than men by a score of 6.07 to 5.90. However by senior year the men think it is more difficult than the women, 5.84 to 6.02.

***Figure 4**: Relative proportions of Visual and Verbal Learners among Current Biomedical Engineering Students at Drexel (**Visual** learners grasp material better when presented through visual means – graphs, charts, animations, etc. while **verbal** learners are most effective at learning using language – either written or spoken – as the means of information transmittal[11])*

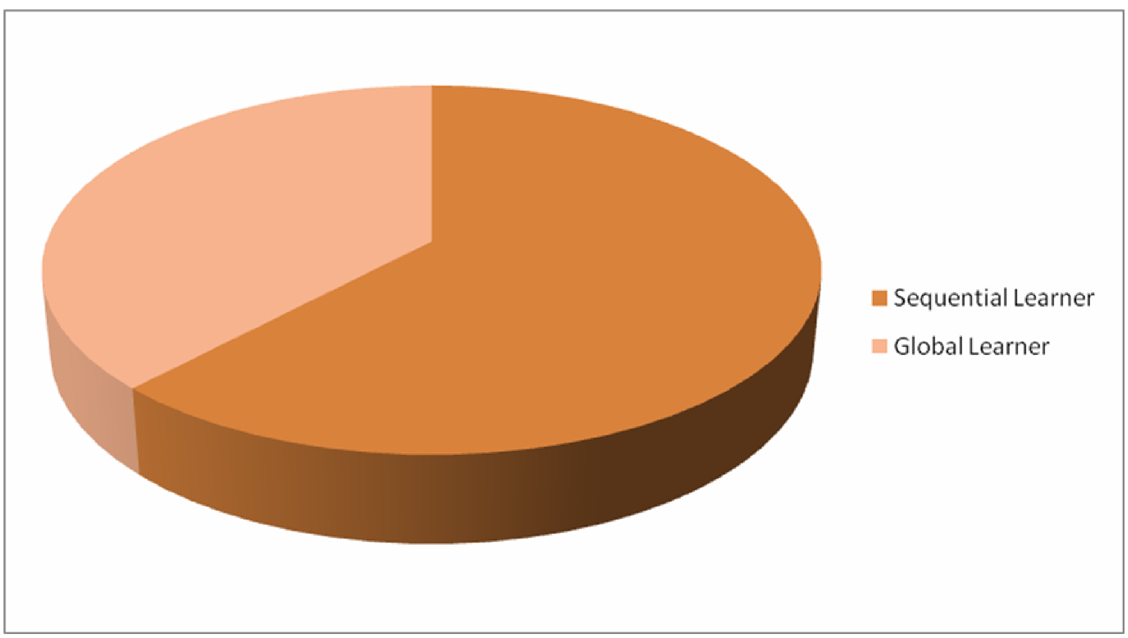


The results from Gardner's Multiple Intelligence survey indicated several similarities across Drexel's biomedical engineering classes and between gender. For instances they all ranked first in logical mathematical intelligence and had linguistic and naturalistic intelligences at the bottom. Furthermore, in analyzing the index of learning styles, all students showed very similar proportionality between active versus reflective learning styles as well as between visual versus verbal learning approaches (Figures 3 and 4).

We are just now completing data collection and beginning various analyses to determine the practical implications of these observations. The word 'practical' was not chosen lightly. It would do little good to design an approach that would be too complex and/or labor intensive to be generally implemented. It is also important to note that results can be statistically significant but yet have little practical consequence. For example, suppose a result indicated that 25% of the variance on a particular performance criterion was due to learning styles. Depending on sample size, this could easily be statistically significant but unless it can be determined how learning style affected outcomes and thus whether or not practical intervention is possible, there is little use to which the data can be put. One advantage of this project is that data are collected on both student and faculty characteristics and interactions between these factors can provide the basis for possible intervention as described by the following example.

The question of the practical utility of collecting such data has been at least partially answered in the case of one of the authors (Papazoglou) and the impact of such data on the teaching of a sequence of senior courses in Biomaterials. As shown in Figure 5, the majority of students in the School are sequential, as opposed to global, learners (62% vs. 38%). What this means is that her students prefer having material presented as a series of small steps from which they will derive an overall understanding – a kind of 'bottom up' method. Dr. Papazoglou, however, is a global thinker and was using a 'big picture' approach in her instructional delivery. She was providing an overall perspective first and then expecting her students to fill in the steps once the overall approach was ascertained – a type of 'top-down' methodology. One apparent result of this instructor-student mismatch was poor student course evaluations –when the global approach was being used, 42% of registered students gave the initial biomaterials course low scores on organization and 35% complained that it took them 4-5 lectures to understand how to approach the class. After recognizing the students' learning style, Dr. Papazoglou altered her instructional lessons to be more sequential, using a step-by-step approach to cover the material. The initial implementation of this methodology resulted in a reduction in the number of students scoring the course low on organization (26% down from the original 42%) and the complete elimination of complaints that the course was difficult to follow (down from 35%). By the second iteration, the number of students indicating poor course organization was down to 10% and student participation had substantially increased. Thus, having the information about the specific learning styles of her students in time to adjust her instructional delivery enabled Dr. Papazoglou to enhance those students' educational experience. Future studies will focus on other student characteristics, the interactions of these characteristics with faculty instructor teaching styles and the effect these interactions have on metrics of student performance across the entire curriculum.

Figure 5*: Relative proportions of Sequential and Global Learners among Current Biomedical Engineering Students at Drexel (**Sequential** learners prefer to have information presented in a series of steps, each building on the previous material, while **global** learners process information holistically from a large, overall perspective.[11])*



A caveat must be mentioned in terms of enhancing student learning. One possible goal of the IDSS might be a completely differentiated system of instruction where each student is taught only to his or her greatest strengths. Even if the resources and other limitations could be overcome allowing such a system to be implemented, it is not clear that this is a desirable endpoint. Indeed, this may well be setting up students for failure upon graduation since the real world in which they will operate is unlikely to be designed for their individual benefit and to fit their individual styles. Given the rapid pace of change and the progress of globalization, the ability of students to rapidly adapt to new circumstances and opportunities is vital. Data provided by the IDSS can not only be used to implement interventions in instructional design to promote student learning but also to intervene in student learning to promote adaptability, flexibility and a broader perspective.

As indicated above, there is already preliminary evidence that survey data can be used to alter teaching methods and enhance student learning. However, we believe that connecting the surveys together can provide insight into valuable social trends of the student body as well. For example, the Student Lifestyle Impact Surveys appear to indicate a gender difference between male and females students in their approaches to the curriculum. Freshmen females register for fewer classes and credits than their male counterparts. Perhaps through negative stereotyping or other social stigma, freshmen women may be intimidated by the course work/field. This observation was reinforced by the initial higher perceptions of difficulty indicated by females in the Engineering Perspectives survey. However, if one were to initiate changes in the curriculum on the basis of the freshman data alone, the changes are likely to result in unintended consequences. Data collected on pre-juniors and seniors demonstrate that as the women progress through the program, they take on ***more*** courses than their male counterparts. Females are also more likely to work in part time jobs and participate in extracurricular activities more often; perhaps as a result, women engage in slightly fewer hours of homework per week. Of course these results would have to be extended beyond this initial study for consistency and validity but they do provide an important foundation for future analysis.

Conclusion

Data collection is actually not a significant issue in assessment. There are many methods and techniques available for the collection and storage of assessment results. The real problem is getting the right data to the right people in right format and at the right time. This is a knowledge management issue that can be solved in large measure through the creative use of computer information systems. The use of an integrated KM platform, such as the one presented in this work has demonstrated proven capabilities to manage information and deliver real-time data to all user groups appropriately. Through the development of faculty-friendly IDSS structures this work can lead to enhanced student learning, continuous quality improvement and the necessary validation to support accreditation.

It is also important to build into any such system the flexibility to adapt to new circumstances. In terms of our approach, the data and analysis methods embodied by the AEFIS platform are designed to allow changes in data interpretation and use as circumstances – and people – change. Thus, the system is being implemented to provide a continuous and on-going process of data collection, analysis, use and evaluation so that as the student body changes – and their needs and the needs of society change – instructional delivery can adapt.

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Bibliography

1) Armstrong. T. (2000). *Multiple Intelligences in the Classroom, 2nd Edition*. Association for Supervision and Curriculum Development.

2) Anderson, L and Krathwohl, D. (2001). *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Addison, Welsey, Longman

3) Borg, M. and Stranahan, H. (2002). Personality type and student performance in upper-level economics courses: The importance of race and gender. *Journal of Economics Education*, 33: 3-14.

4) Cole, J. and Denzine, G. (2004). "I'm not doing as well in this class as I'd like to": Exploring achievement, motivation and personality. *Journal of College Reading and Learning*, 34: 29-44.

5) Diaz-Lefebvre, R. (2004). Multiple intelligences, learning for understanding, and creative assessment: Some pieces to the puzzle of learning. *Teachers College Record*, 106: 49-57.

6) DiMuro, P. and Terry, M. (2007). A matter of style: Applying Kolb's learning style model to college mathematics teaching practices. *Journal of College Reading and Learning*, 38: 53-60.

7) Dunn, R. and Stevenson, J. (1997). Teaching diverse college students to study with a learning-styles prescription. *College Student Journal*, 31: 333-339.

8) Entwistle, N. aand McCune, V. (2004). The conceptual basis of study strategy inventories. *Educational Psychology Review*, 16: 325-345.

9) Felder, R and Spurlin, J, (2005). Applications, reliability and validity of the index of learning styles. *International Journal of Engineering Education*, 21: 103-112.

10) Felder, R. (1995). A longitudinal study of engineering student performance and retention. IV. Instructional methods and student responses to them. *Journal of Engineering Education*, 84: 361-367.

11) Felder, R. and Silverman, L. (1988). Learning and teaching styles in engineering education. *Engineering Education*, 78: 674-681.

12) Felder, R., Felder, G., and Dietz, E.J. (1998). A longitudinal study of engineering student performance and retention: V. Comparisons with traditionally-taught students. *Journal of Engineering Education*, 87: 469-480.

13) Felder, R.M., Felder, G. and Dietz, E.J. (2002). The effects of personality type on engineering student performance and attitudes. *Journal of Engineering Education*, 91, 3-17.

14) Gardner, H. (1999). *Intelligence reframed: Multiple Intelligences for the 21st century*. New York: Basic Books.

15) Graff, M. (2003). Learning from web-based instructional systems and cognitive style. *British Journal of Educational Technology*, 34: 407-418.

16) Information Builders. (2010). Decision Support Systems – DSS (definition). Downloaded from http://www.informationbuilders.com/decision-support-systems-dss.html

17) Ishiyama, J. (2005). The structure of an undergraduate major and student learning: A cross-institutional study of political science programs at thirty-two colleges and universities. *The Social Science Journal*, 42: 359-366.

18) Kunzman, R. (2002). Extracurricular activities: Learning from the margin to rethink the whole. *Knowledge Quest*, 30: 22-25.

19) Li, O., McCoach, B., Swaminathan, H. and Tang, J. (2008). Development of an instrument to measure perspectives of engineering education among college students. *Journal of Engineering Education*, 97: 47-56.

20) Litzinger, T, Lee, S. H., Wise, J., and Felder, R. (2007). A psychometric study of the index of learning styles. *Journal of Engineering Education*, 96: 309-319.

21) Martin, G.P. (2000). Maximizing multiple intelligences through multimedia: A real application of Gardner's theories. *Multimedia Schools*, 7: 28-33.

22) McCoog, I.J. (2007). Integrated instruction: Multiple intelligences and technology. *The Clearing House*, 81: 25-28.

23) National Science Board (2007). Moving Forward to Improve Engineering Education. *NSB-07-122* (November 19, 2007).

24) Noble, T. (2004). Integrating the revised Bloom's taxonomy with multiple intelligences: A planning tool for curriculum differentiation. *Teachers College Record*, 106: 193-211.

25) Raven, M., Cano, J., Carton, B. and Shelhamer, V. (1993). A comparison of learning styles, teaching styles and personality styles of preservice Montana and Ohio agriculture teachers. *Journal of Agricultural Education*, 34: 40-50.

26) Terry, M. (2001). Translating learning style theory into university teaching practices: An article based on Kolb's experiential learning model. *Journal of College Reading and Learning*, 32: 68-85.

27) Trianatafillou, E., Pomportsis, A., Demetriadis, S. and Georgiadou, E. (2004). The value of adaptivity based upon cognitive style: An empirical study. *British Journal of Educational Technology*, 35: 95-106.

28) Van der Hulst, M. and Jansen, E. (2002). Effects of curriculum organization on study progress in engineering studies. *Higher Education*, 43: 489-506.

29) White, J., Shiffman, R., Middleton, B. and Caban, T.Z. (2008). A National Web Conference on Using Clinical Decision Support to Make Informed Patient Care Decisions. Downloaded from http://healthit.ahrq.gov/images/sep08cdswebconference/textonly/index.html

30) Winston, R.B. (1990). The student developmental task and lifestyle inventory: An approach to measuring students' psychosocial development. *Journal of College Student Development*, 31: 108-120.