AC 2007-417: TECHNOLOGY ENABLED SUPPORT MODULES FOR ENGINEERING MANAGEMENT

Stuart Kellogg, South Dakota School of Mines and Technology

Stuart D. Kellogg, Ph.D., Dr. Kellogg is a Professor of Industrial Engineering at the South Dakota School of Mines & Technology where he currently serves as coordinator of the Industrial Engineering and Technology Management programs. In addition to pedagogical issues related to engineering education, his research interests include applied and numerical probability models in the industrial environment. He has published works Mathematics and Computers in Simulation, Proceedings of IIE Research Conference, Quality Engineering, and Proceedings of the Joint Statistical Meetings. Dr. Kellogg is a member of the Institute of Industrial Engineers and the American Society for Engineering Education.

Technology Enabled Support Modules for Engineering Management

Abstract

A common problem with the Carnegie unit of instruction is that it tends to promote the concept that engineering management tools are isolated units of instruction. Consequently, students often fail to see the connections between these tools and the applications within the disciplines. As a mechanism for promoting just-in-time review and supplemental instructional support, the industrial engineering department embarked on a long term project to provide online self-correcting modules in the areas of finance, entrepreneurship, economic valuation, and management science tools. This paper discusses a strategy for designing web-based tutorials that can help provide an element of scaffolding necessary for a developmental approach while simultaneously addressing alternative learning styles. Tutorial examples along with preliminary assessment results are provided.

Introduction

Calls for greater accountability in higher education are more strident than ever. Although stated in a variety of formats, these calls may almost always be couched within two distinct but overlapping developmental models. The first centers on the requirement to better engage an increasingly diverse learning community and the second is to develop better thinking skills. It is in the second area that a preponderance of research evidence suggests that universities fall woefully short. On a 7 point reflective judgment scale[1], students enter a university around level 3.5 and matriculate with an average score of 3.8 - well below the theoretical optimum offered by brain research and that level desired by industry.

To address these concerns, the Industrial Engineering program at SDSM&T has embarked on a long-term effort to reshape the existing curricular components by building developmentally appropriate integrative threads throughout the undergraduate curriculum. Curricular elements of the threads include technology enabled learning, service learning, business plans, and enterprise team projects. Using the Steps for Better Thinking Model[2] as the developmental umbrella, all curricular elements are strategically placed within the curriculum to provide both an integrative thread between the major components as well as a developmental thread for improving complex thinking skills. The primary role of the technology enabled support modules is to provide the foundational scaffolding necessary to develop more complex reasoning while simultaneously attempting to address alternative learning styles. To develop this more fully, it is first necessary to understand the developmental model adopted by the industrial engineering faculty.

Developmental Theory

A growing body of research suggests that in order to help students develop more complex thinking skills one needs to provide a curriculum that is challenging while simultaneously providing the foundational support necessary for student success. While some researchers focus on an adaptive curriculum based on a student's learning preference curve or typology[3,4], others suggest that a curriculum focused on the social aspects of student learning may be more productive[5-8]. Still others suggest that focusing on students' intellectual development can lead to significant learning gains[9,10]. The Industrial Engineering program seeks to increase student involvement through three distinct but overlapping developmental thrusts.

1. Social Development
2. Typological Models
3. Intellectual Development

Thus, a conceptual framework for student development adopted by Industrial Engineering is shown below in Figure 1.

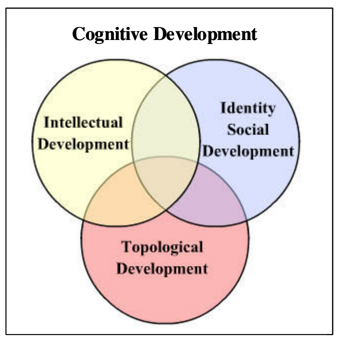


Figure 1. Conceptual Framework for Student Development

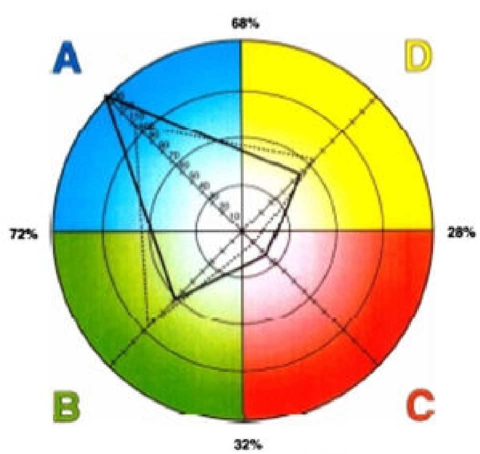
In this model, we interpret typological development to mean student awareness of, and an appreciation for, alternative learning styles and thinking preferences both for the individual student and for others. This approach to student development is not new and is similar to the notion of diversity proposed by Felder and Brent[11].

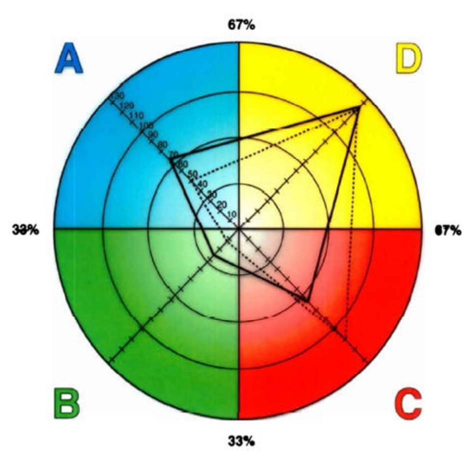
Identity/Social Development
Several authors[6,7] suggest that the more students are involved in both the academic and social aspects of collegiate life, the more they learn. Goodsell and Tinto[7], strong proponents of learning communities, stress that a student's college life can affect persistence. Chickering's[8] seven vectors of development that stress time on task, faculty-student and student-student interaction cumulatively contribute to self-identity. In industrial engineering stronger connections between the social and academic aspects of campus life are accomplished through key components that include service learning, student organizations, and enterprise teams.

Typology/Diverse Learning Needs
Althought the retention rate in engineering education is well known, it is not particularly well understood. While many continue to believe it is simply a matter of curricular rigor, the research

evidence begins to provide a more comprehensive view of a fairly complex issue. In a landmark comprehensive study of student engagement, Astin[5] suggests social communities, student-student interaction, and faculty-student interaction may have a stronger implication for students leaving than does academic rigor. In her studies, Sheila Tobias[12] suggests that students often leave because of a mismatch in learning needs and instructional delivery. Seymour and Hewitt[13], suggest career advising, limited communication, and faculty research orientation may be a contributing factor for student disconnect within the engineering disciplines. Smith, Sheppard, Johnson, and Johnson[14] suggest a critical need for increased pedagogies of engagement. Felder and Brent[11] suggest a greater need to understand student differences, both typologically and developmentally and provide a comprehensive listing for both.

Regardless of the typology used, all models suggest that individuals tend to have different strengths and ways of solving more complex problems. The primary impetus for considering typology is three-fold. First, understanding their individual learning styles can help students identify and strengthen areas of weakness in the problem solving cycle. Secondly, understanding different preference curves and alternative approaches to problem solving is becoming a requirement for multi-disciplinary team processes and creative problem solving. The third, and perhaps more compelling reason, is the need for engineering educators to more adequately address increasingly diverse learning needs. Consider for example, the thinking preference curves using the Herrmann Brain Dominance Inventory (HBDI) for two students shown below.





(a) HBDI Student A (b) HBDI Student B

Figure 2. Herrmann Brain Dominance Thinking Curves for Two Students A and B

By its nature, much of the engineering curriculum resides in quadrant A. For student A, there is a strong match between the curriculum and the student's thinking preference curve in quadrant A. Student B, on the other hand, might have the analytical and quantitative skills needed for success, but also exhibits strong thinking preferences for the experimental and feeling self of the whole brain model[15]. As a result, while student B may have strong technical skills and an ability to work on a creative multi-disciplinary team, student B is also more likely to feel more disconnected from the analytical approach predominately found in the traditional engineering curriculum[16].

For purposes of this paper, we approach diverse learning needs through a variety of experiential opportunities and exposure to alternative learning styles through course materials and team projects. Curricular elements and support modules do not address specific learning needs that require specialized training, support, or assistive technologies.

Intellectual Development

Regardless of the developmental model used (see, for example, Perry[17], King and Kitchener[1], and Lynch and Wolcott[2]), all developmental models support the concept of systematically providing the appropriate support or "scaffolding" necessary to help students transition from one developmental level to the next. Daloz[18] suggests that in order for growth to occur, there must be a proper balance of both a challenging curriculum and support for the individual learner. A program that provides neither a challenging curriculum nor support for the learner tends to lead to stasis. Conversely, students who encounter a challenging curriculum without having the support mechanisms necessary will actually retreat on the developmental scale.

Within the Steps for Better Thinking[2] (Figure 3) model, the challenge is provided within a developmental context. That is, students cannot synthesize information or envision new information requirements if developmentally they are at the identification or exploratory stage. The support structure requires that developmental threads are constructed in a manner that systematically helps students move from one stage to the next. In addition students require the foundational skills or knowledge base necessary in order to successfully transition from one developmental level to the next. Further, this foundational knowledge or "scaffolding" is required for all levels.

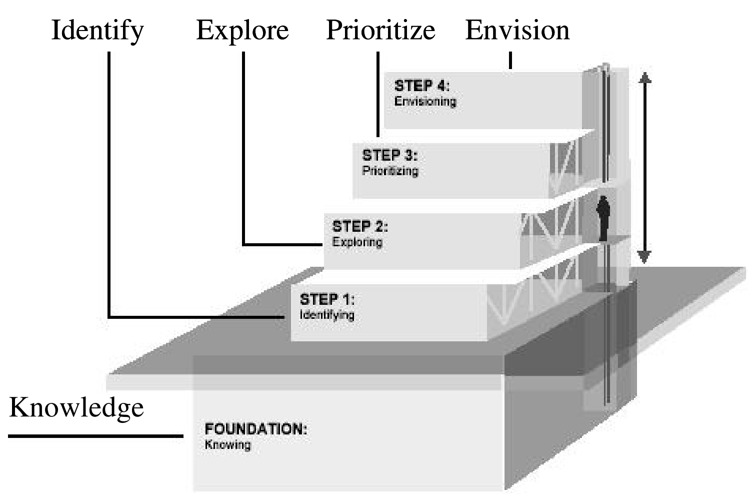


Figure 3. Steps for Better Thinking Model

It is in this foundational knowledge base that the traditional curriculum most often struggles. The Carnegie unit of instruction tends to encourage students to view units of instruction as isolated packets of information. Once a student completes probability and statistics, for example, students tend to do a "brain flush" because they fail to see the connections between these courses and the applications used elsewhere in the curriculum. The remainder of this paper discusses the rationale for utilizing technology support modules as one mechanism for providing the foundational "scaffolding" needed to reinforce these connections and aid the developmental transitions.

Historical Assessment; Building the Need

Industrial Engineering students are required to complete a total of nine credits in probability and statistics. Yet FE data collected and analyzed over a five year period suggests that, except for queuing theory and simulation, IE students score slightly below the national average for all Industrial Engineering students completing the FE exam in the area of statistical reasoning (see Figure 4 below).

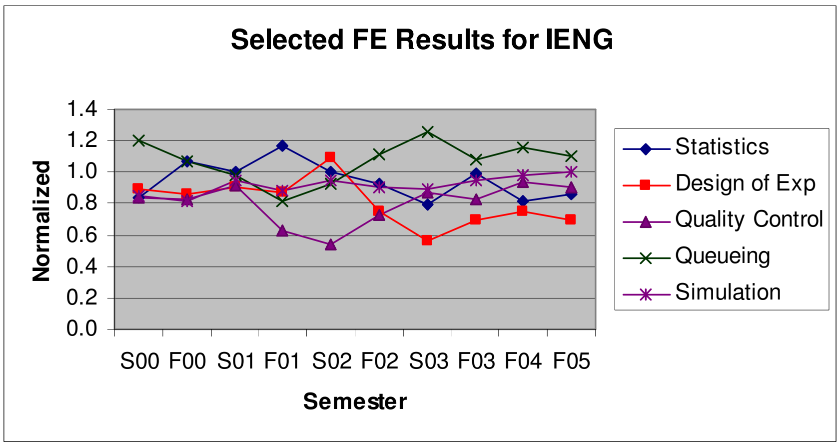


Figure 4. Selected FE Results for Industrial Engineering

To explore this problem further, industrial engineering and mathematics faculty designed a simple concepts instrument in probability and statistics to determine if the problem is one of complex statistical reasoning or if the problem stems from the foundational knowledge base in the Steps model (Figure 3). The concepts inventory was given to all full time onsite industrial engineering students completing a second semester course in probability and statistics or the senior level course in simulation. Despite fairly rigorous coursework in probability and statistics, Figure 5 indicates that students often struggle with fundamental concepts.

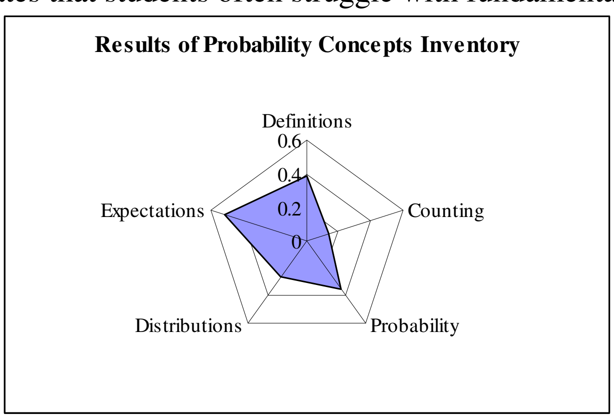


Figure 5. Results of Probability Concepts Inventory (2003)

Course assessments indicated similar problems with fundamental statistical concepts within the context of industrial and engineering management applications. Further, course assessments reinforced the notion that in order to develop more complex reasoning skills in various aspects of engineering management, there was a significant need to strengthen the underlying foundational knowledge base of most engineering students. Considerable research supports the efficacy of technology enabled support modules[19,20] as a viable mechanism for building connections and providing just-in-time foundational support. As a result, before the department could embark on a long term project to increase student complex reasoning skills, a necessary first step was to develop a set of independent multi-media modules that could provide a portion of the foundational "scaffolding" necessary to aid developmental transitions.

Multi-media Design

Besides principles of good practice in multi-media design[20,21], a number of important criteria were considered in the development of the review modules. Specifically,

- All materials should be developed for asynchronous mode.
- Review modules should be relatively short and should provide opportunities for exploration of applications related to the topic.
- Embedded online interactive exercises should be self-correcting.
- The mode of delivery must be technologically compatible at point of delivery. Download times, where applicable must be kept to a minimum.
- Material should be readily accessible for both just-in-time review and on an ongoing basis.
- Whenever possible, modules should address multiple learning styles with student controlled navigation.

The last two criteria are particularly significant in the overall design of the material. Although interactive modules can be tied to course syllabi for just-in-time review, as such they provide little opportunity for students to begin building connections between curricular components. In that regard, the department now has stand alone websites providing supplementary information in the areas of probability, statistics, operations research, business, and general management. Although considerable work remains to provide a cohesive flow between modules, each website provides an organized set of materials that may be accessed by any student on or off campus at any time. In addition, independent self-correcting modules may be accessed directly from a course syllabus on an as-needed basis. All interactive units were developed using either macro-media AuthorWare or Flash software. Sample modules follow in the next section. A summary of department sponsored sites and review materials are given in Table A.1 in Appendix A.

Sample Support Modules

Figure 6 below shows a sample module demonstrating sensitivity analysis for a simple two variable, three constraint linear programming model.

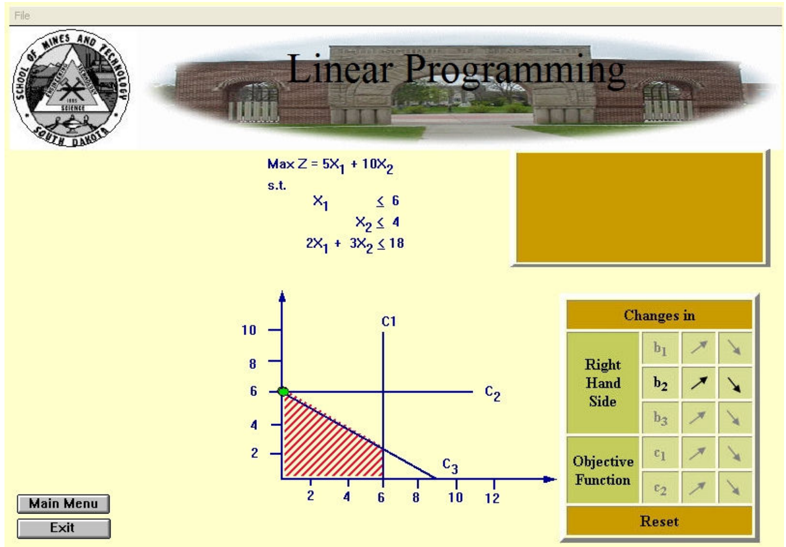
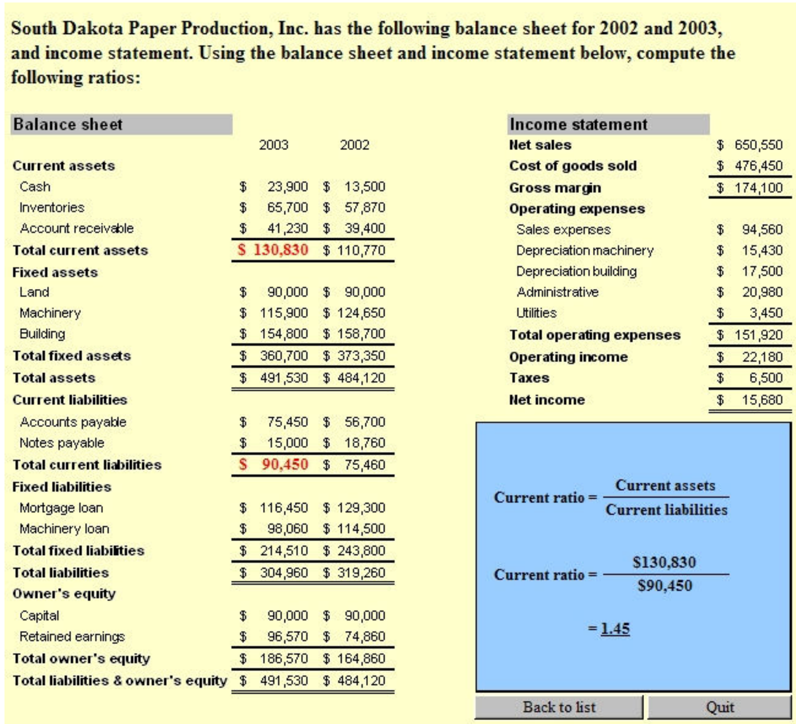


Figure 6. Demonstrating Sensitivity Analysis in Linear Programming

While classroom instruction focuses on the simplex algorithmic approach to sensitivity analysis, the support modules allow students to see visually what happens to the feasible region, boundary constraints, and the optimal solution as different objective or constraint coefficients are selected. While theory and practice require a thorough understanding of the simplex method, these modules provide a mechanism that enables students to better connect theory with conceptual understanding.

A second example, shown below in Figure 7, demonstrates an interactive exercise in financial analysis. In this module, the student is asked to calculate a financial ratio from a list. The student is given three attempts to calculate a correct number before returning to the ratio list. If, on the third attempt, the student still fails to calculate the correct ratio, the correct areas of the financial statements are highlighted and a dialogue box demonstrates the correct calculation. While the linear programming model promotes a more conceptual framework of the simplex method, this module simply provides a mechanism for students to review various components of financial analysis that are utilized in a variety of engineering management applications including cost estimating, operations analysis, product development, and product commercialization. By providing an online review module, faculty can more quickly move to the open-ended discussions needed for complex reasoning.


South Dakota Paper Production, Inc. has the following balance sheet for 2002 and 2003, and income statement. Using the balance sheet and income statement below, compute the following ratios:

Balance sheet	2003	2002
Current assets		
Cash	$ 23,900	$ 13,500
Inventories	$ 65,700	$ 57,870
Account receivable	$ 41,230	$ 39,400
Total current assets	$ 130,830	$ 110,770
Fixed assets		
Land	$ 90,000	$ 90,000
Machinery	$ 115,900	$ 124,650
Building	$ 154,800	$ 158,700
Total fixed assets	$ 360,700	$ 373,350
Total assets	$ 491,530	$ 484,120
Current liabilities		
Accounts payable	$ 75,450	$ 56,700
Notes payable	$ 15,000	$ 18,760
Total current liabilities	$ 90,450	$ 75,460
Fixed liabilities		
Mortgage loan	$ 116,450	$ 129,300
Machinery loan	$ 98,060	$ 114,500
Total fixed liabilities	$ 214,510	$ 243,800
Total liabilities	$ 304,960	$ 319,260
Owner's equity		
Capital	$ 90,000	$ 90,000
Retained earnings	$ 96,570	$ 74,860
Total owner's equity	$ 186,570	$ 164,860
Total liabilities & owner's equity	$ 491,530	$ 484,120

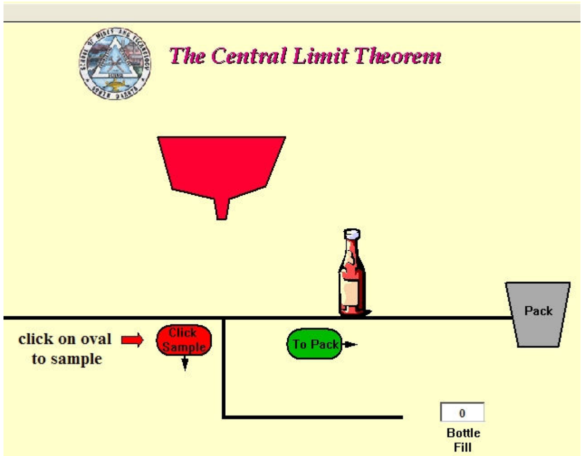
Income statement	
Net sales	$ 650,550
Cost of goods sold	$ 476,450
Gross margin	$ 174,100
Operating expenses	
Sales expenses	$ 94,560
Depreciation machinery	$ 15,430
Depreciation building	$ 17,500
Administrative	$ 20,980
Utilities	$ 3,450
Total operating expenses	$ 151,920
Operating income	$ 22,180
Taxes	$ 6,500
Net income	$ 15,680

Figure 7. Online Interactive Exercise in Financial Analysis

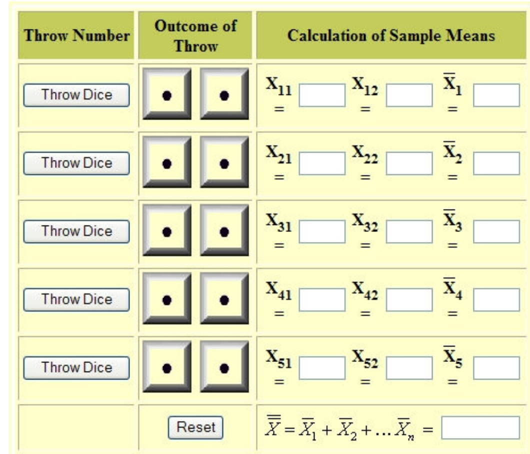
A distinct advantage of technology support modules is that support modules may be modified for alternative learning styles. Figure 8 below demonstrates the alternative approaches used to discuss the central limit theorem as they apply to different quadrants of the Kolb experiential model.

While each interactive module demonstrates the central limit theorem, each presents the theorem from a different perspective. Traditional classroom development of the theorem is accomplished through a rigorous application of moment generating functions. While useful for students with a strong penchant for mathematics (assimilators), a formal mathematical approach does work for many students. Most engineering students (convergers) tend to understand a more heuristic approach through a two variable discrete convolution matrix. Still others (accommodators and divergers) find an experimental approach to the central limit theorem more consistent with their particular learning style.

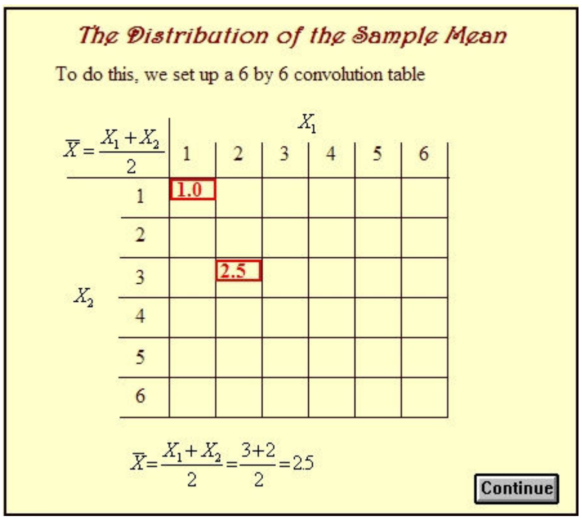
While the department has consciously made every effort to offer a variety of support modules that address alternative learning styles, few are as distinctive as the central limit theorem. Some modules attempt to approach content from a global perspective and some from a linear perspective. Most simply attempt to provide an opportunity for online review by using a visual representation of the concept as apposed to a symbolic or mathematical description. Some students find the online self-assessment quiz useful while others prefer the modules that offer self-correcting feedback. While first year students are given the Kolb LSI, there is no direct link to any particular module based on an individual learning style. Most students simply explore those units that seem helpful to the understanding of the material.



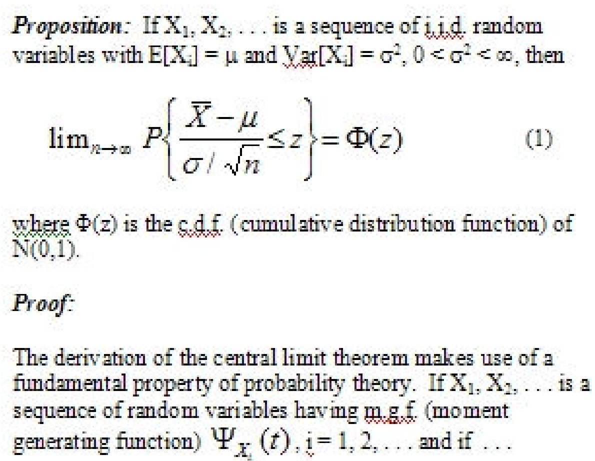
(a) Accomodator



(b) Diverger



(c) Converger



(d) Assimilator

Figure 8. Central Limit Module as Applied to Alternative Learning Styles

Assessment

The online interactive modules require considerable effort to develop, test, and implement. While the intent is to create a mechanism to reduce in-class review and to help students build connections between curricular elements, that effort is lost if students perceive little value in the material and fail to take advantage of the online support. Although it is difficult to measure student gains in conceptual knowledge, the probability and financial web sites include a statistical counter that tracks student use during the semester to provide some measure of usefulness. Page loads and the number of visitors to the finance web site is shown below in Figure 9.

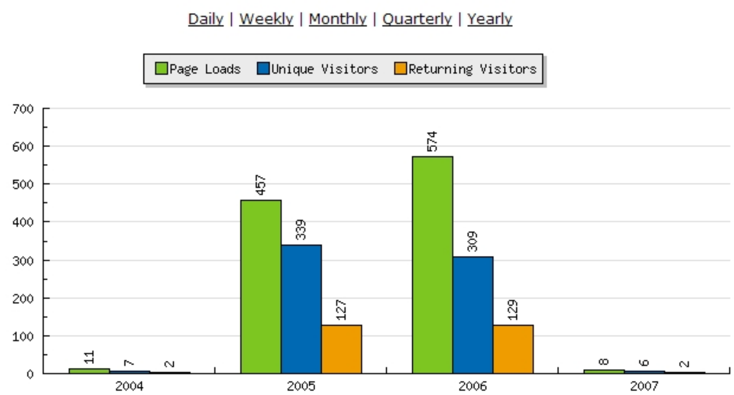


Figure 9. Page Loads, Unique Visitors, and Returning Visitors for ProbWeb

While page site visits provide some measure of relevancy for student interest, actual time on site provides a more robust measure of module usefulness. Figure 10 shows the duration of a site visit for the financial web site. While many students find little practical benefit from the finance modules, it is clear that a significant number of students spend considerable time with a number of the review modules. The most recent activity indicates that nearly 20% of the students spend over an hour at the site reviewing material presented in one or more modules.

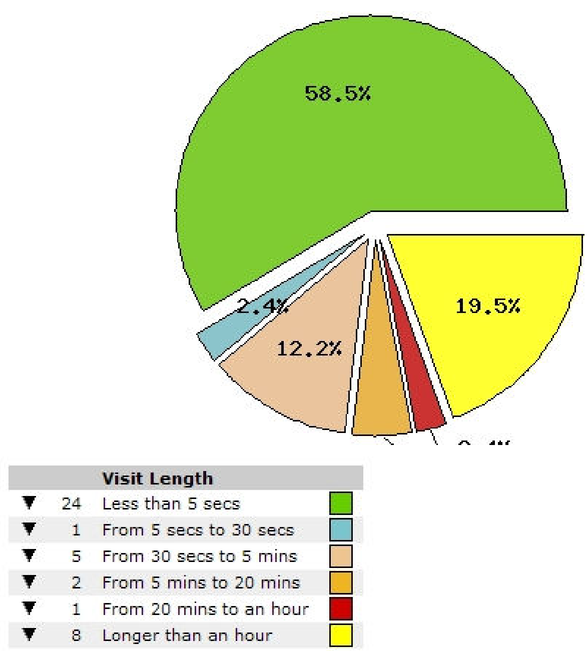
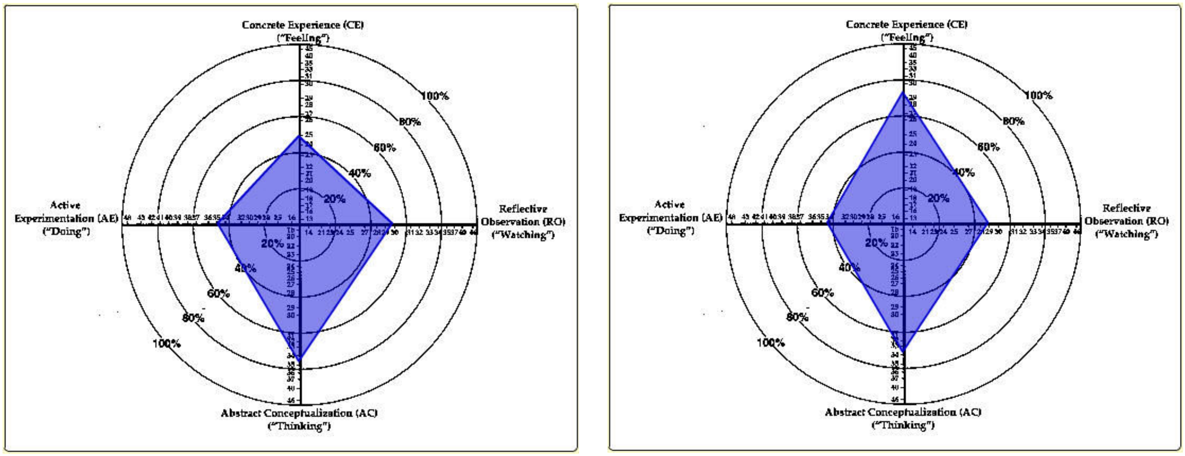


Figure 10. Visit Length for Finance Web Site

While the FE and concepts inventory show traces of improvement, it is too soon to determine if true conceptual gains are being made. However, of greater interest to the faculty is if curriculum modifications that have been implemented thus far have had an impact on better serving the diverse typologies of the student population. In this regard, Kolb learning preference curves have been tracked for industrial engineering majors for the past five years and are compared to those of first year students. Results in Figure 11 below indicate that gains have been made in retaining students with diverse learning styles in Industrial Engineering. That gains have been made is further supported by continued positive enrollment trends in Industrial Engineering.



(a) All Campus Freshman   (b) Industrial Engineering Seniors

Figure 11. LSI Comparison; IE Seniors to Entering Freshman

Although Figure 10 indicates that some gains have been made in addressing diverse learning styles, it would be illogical to assign those gains to the supplementary support modules. Nevertheless, Figure 11 does suggest that a holistic developmental approach adopted by the department does have some merit. What remains to be seen is if similar gains can be demonstrated in improving student complex reasoning skills. Baseline data has been collected but is not yet available at the time of this writing. Nevertheless, the faculty remain convinced that by providing a variety of experiential opportunities and complementary avenues of support, significant gains in student growth and development can be achieved.

Conclusions and Future Work

The Industrial Engineering department embarked on an ambitious plan five years ago to more effectively address diverse learning needs through a variety of experiential opportunities. Data consistently shows we have been remarkably successful. The second part of this initiative is to ensure that diverse learners also possess the complex thinking skills needed by industry. By providing an experiential framework that allows for more complex thinking at distinct stages of student developmental growth, the faculty remain convinced that significant gains can be made. While the department is gradually shifting to phase II of this project, continued development of the foundational skills needs to continue. Additional modules in statistics, management science, and economic valuation are required. Recent effort has also included providing stand alone instruction that will allow students to begin building better connections between the foundational skills taught in earlier courses and the engineering management applications utilized throughout the curriculum.

References

[1] King, P. M. and K. S. Kitchener, *Developing Reflective Judgment*, Jossey-Bass, San Francisco, 1994.

[2] Lynch, C. L. , S. K. Wolcott, and G. E. Huber, "Steps for Better Thinking: A Developmental Problem Solving Process," http://www.WolcottLynch.com, 2002.

[3] Sims, R., and Sims, S., *The Importance of Learning Styles, Understanding the Implications for Learning, Course Design, and Education*, Greenwood Press, 1995.

[4] Rosati, Peter, "Specific Differences and Similarities in the Learning Preferences of Engineering Students," *Proceedings of the Frontiers in Education Conference*, San Juan, Puerto Rico, November 1999.

[5] Astin, A., *What Matters in College? Four Critical Years Revisted*, Jossey-Bass, 1993.

[6] Astin, A., "Student Involvement: A Developmental Theory for Higher Education," *Journal of College Student Personnel*, 25, 297-308, 1984.

[7] Goodsell, A., and V. Tinto. "Freshman Interest Groups and the First Year Experience: Constructing Student Communities in a Large University." *Journal of the Freshman Year Experience* 6(1) (1994): 7-28.

[8] Chickering, A. and S. C. Ehrmann, "Implementing the Seven Principles: Technology as Lever," *AAHE Bulletin,* October, pp. 3-6, 1996. (http://www.tltgroup.org/programs/seven.html)

[9] Genalo, L. J., D. A. Schmidt, and M. Schiltz, "Piaget and Engineering Education," *Proceedings of the American Society for Engineering Education*, June 2004.

[10] Streveler, R. A., B. M. Moskal, and R. L. Miller, "The Center for Engineering Education at the Colorado School of Mines: Using Boyer's Four Types of Scholarship," *Proceedings of the Frontiers in Education Conference*, Reno, NV, October 2001.

[11] Felder, R. M., and R. Brent, "Understanding Student Differences," Journal of Engineering Education, vol. 94, no. 1, 57-72, January 2005.

[12] Tobias, S., *They're Not dumb, They're Different*, Research Corporation, 1990.

[13] Seymour, E. and N. Hewitt, *Talking About Leaving; Why Undergraduates Leave the Sciences*, Westview, 1997.

[14] Smith, K., Sheppard, S., Johnson, D., and Johnson, R., "Pedagogies of Engagement: Classroom-Based Practices", *Journal of Engineering Education*, vol 94, no. 1, January 2005.

[15] Herrmann, N., *The Creative Brain*, The Ned Herrmann Group: Brain Books, 1995.

[16] Lumsdaine, E. and M. Lumsdaine, *Creative Problem Solving: Thinking Skills for a Changing World*, 2nd ed., 1993.

[17] Perry, W. G., Jr., *Forms of Intellectual and Ethical Development in the College Years*, Holt, Rinehart and Winston, Inc., New York, 1970.

[18] Daloz, L.A., *Mentor: Guiding the Journey of Adult Learners*, Josey-Bass, 1999.

[19] Riggs, B., Poli, C., and B. Woolf, "A Multimedia Application for Teaching Design of Manufacturing," *Journal of Engineering Education*, vol. 87 no. 1, 63-70, January 1998.

[20] Verduin, J. and T. Clark, *Distance Education: The Foundations of Effective Practice*, Josey-Bass, 1991.

[21] Wallace, D., and S. Weiner, "How Might Classroom Time be Used Given WWW-Based Lectures?" *Journal of Engineering Education*, vol. 87 no. 3, 237-248, July 1998.

Appendix A

Table A. 1. Review Pages and Sample Support Modules

Finance: http://ie.sdsmt.edu/finance/finance.html	
Time Value of Money	Includes a loan calculator, loan schedule template, compounding tables, and self-correcting quiz randomly selected in groups of 10.
Economic Valuation	Interactive exercises capturing effective interest, investment worth, depletion allowance and decision trees
Personal Finance	Uses time value of money concepts to demonstrate wealth building. Interactive flash plots show accumulated wealth after n years on both a before and after inflationary consideration. Includes a loan calculator, loan schedule template, retirement template
Financial Analysis	Interactive exercises demonstrating financial sheets, financial statement analysis, process costing, and overhead calculations
ProbWeb: http://ie.sdsmt.edu/probweb/prob.html	
Probability Review	Includes a discussion of basic and conditional probability
Memoryless Property (Exp)	Interactive derivation of the memoryless property of the exponential distribution and several sample applications.
Probability Distributions	Provides information relevant to reliability and simulation modeling for 9 continuous distributions. All distributions include interactive plots that allow users to explore distribution characteristics
Quiz	Quiz module allows students to self-test on basic probability concepts
Operations Research: http://ie.sdsmt.edu/orweb/or.html	
Linear Programming	LP Module includes an interactive development of a prototype model, demonstration of interactive graphical solution, and interactive demonstration of sensitivity analysis.
StatWeb: http://ie.sdsmt.edu/statweb/probstat.htm	
Central Limit Theorem	Features a variety of interactive demonstrations of CLT. A heuristic derivation is included demonstrating normality, sample mean, and sample variance. Formal derivation of CLT using mgf.
Maximum Likelihood Estimator	Module includes an explanation of point and interval estimates as well as maximum likelihood estimates. Downloaded MLE software available. Software includes estimator routines for 9 continuous distributions as well as 3 options for goodness of fit tests.
Statistic Tables	Provides online access to many of the common statistics tables
Trend Analysis	Allows students to manually fit a trend line to randomly generated linear data. Module includes additional information on the derivation of least squares parameters.
Functions: http://ie.sdsmt.edu/functions/functions.htm	
Site includes interactive flash plots of many of the common functions used in the first year including trigonometric functions, exponential, natural logarithm, and the power function.	
New Developments: modules under development	
Information Systems	Minimization tips, multi-media, and database tutorials
Management Web	Links to management resources, leadership, cases
Entrepreneurship	Provide links for business plan development; business resources