AC 2008-2568: TECHNOLOGY ENABLED SUPPORT MODULES FOR THE INVERTED ENTREPRENEURIAL CLASSROOM

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Technology Enabled Support Modules for the Inverted Entrepreneurial Classroom

Abstract

For most engineering disciplines, the curriculum is fairly constrained. Although the new ABET criteria has increased the flexibility to develop a responsive and adaptive curriculum, developing value added curriculum remains a significant challenge. To respond to this challenge, Industrial Engineering has incorporated a modular approach to courses in the business and entrepreneurship area. While use of the modular approach provides increased flexibility for students, it also tends to compress curricular content which significantly increases the challenge of incorporating engaged pedagogies within the classroom. To provide a balance between active learning and increased flexibility, courses were divided into skills oriented classes and courses with a significant active learning component. Skills classes make extensive use of a multi-media approach and independent study options. For courses requiring extensive use of active learning components, an inverted classroom approach is used to provide more extensive delivery of content outside of the regular class time. This paper discusses some of the pros and cons of the inverted classroom, provides some examples of multi-media content delivery, and some preliminary assessment data utilizing this approach.

The Changing Environment

Calls for greater accountability in higher education are more strident than ever. The shift to a global economy, the move to lean management structures, and the need to serve an increasingly diverse learning community requires a new approach to engineering education. It requires a transformative curriculum that not only embraces the changing requirements sought by industry, it requires a model that develops the complex thinking skills required to help industries be successful in today's global market place. While industry and various university advisory boards express a number of issues and proposed attributes for successful engineers of 2020, these attributes and issues may almost always be couched within the following pedagogical concerns:

- There is a need to construct engineering curriculum so as to serve more diverse learners.
- There is a need to help students develop better complex thinking skills.
- There is a need to provide learning environments that more actively engage students on multi-disciplinary team projects.
- There is a need to create an opportunity for value added curriculum, particularly in the areas business, management, and leadership skills.

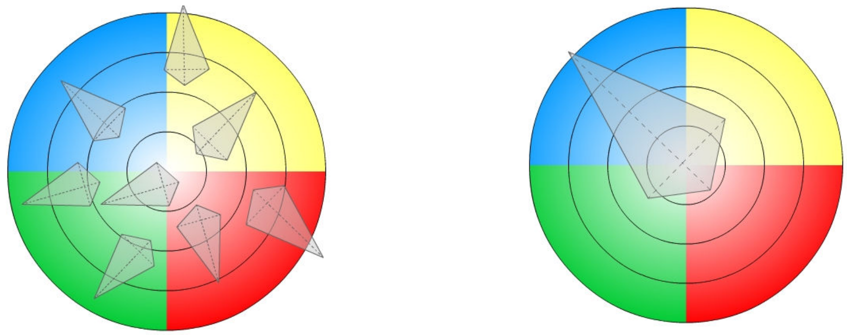
To do this is going to require more active and engaged pedagogies that usually provide some opportunity for experiential learning. In the past, such opportunities were generally restricted to laboratory courses and to capstone design, but much more will be expected in the future. The engineering classroom of the future will almost certainly require active/collaborative learning components in most engineering courses. These components will include team based projects, service learning components, technology enabled support components, inverted classrooms, and a better integration of curricular and co-curricular components. Herein lies the challenge. To do this effectively is going to require resources and faculty time. System constraints work against this. At a time when greater resources need to be available for engineering education, most state funded engineering schools operate in an increasingly constrained environment.

Industrial Engineering embarked on a long term transformative curriculum seven years ago with three fundamental goals in mind. Specifically, within system and logistical constraints, the curricular components should address a number of alternative learning styles. Secondly, the curriculum should engage the students at a deeper level in terms open ended questions and creative problem solving. And, third, to the extent possible, the curriculum should provide opportunities for students to incorporate the value added skills within the confines of the existing curriculum.

To accomplish these goals, the Industrial Engineering program at SDSM&T adopted a transformative approach that focuses on 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. Curricular elements are 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.

Diverse Learners

Retention is likely to be a mantel cry of the administration for the foreseeable future. While faculty reasonably argue that engineering is difficult and should not be undertaken by any but the serious, there is substantial and compelling evidence that many capable students leave engineering not because of inability or the work required to be successful, but because of a disconnect. Elaine Seymour and Nancy Hewitt[1] suggest students leave because of advising or other disconnects with the engineering faculty or curriculum. Felder and Brent[2] suggest a need to design a curriculum that addresses alternative learning styles. To see why this might be so, consider the Herrmann Whole Brain Model[3] shown below.



a. First Year Students b. Senior Engineering Students

Figure 1. HBDI Thinking Preference Profiles for Engineering Students

First Year students, even engineering students, are typically all over the map in terms of learning styles or thinking preference profiles (Fig. 1.a.). However the average thinking preference curve for engineering students tends to be significantly more concentrated in the engineering or rational self of the whole brain model (Fig. 1.b.). While much of the engineering work requires coordination (green), systems design and creative problem solving (yellow), and interpersonal team leadership skills (yellow/red), the traditional curriculum does little to address these alternative perspectives. An interesting note here is that while most engineers tend to have a stronger analytical thinking preference (blue), most entrepreneurs tend to have stronger holistic orientation (yellow), and managers tend to have a stronger task (green) orientation. Consequently entrepreneurs with a strong yellow preference curve tend to visualize and solve problems in a manner that is completely opposite from managers with a strong task (green) orientation. If strong enough, this discord can result in significant conflict even if the overall organizational goals are clearly defined and agreed upon.

Of greater interest to the engineering educator is the mismatch that occurs within the traditional engineering curriculum and the creative problem solving needs required by industry. One can argue (see, for example, Seymour[1], Felder[2], Tobias[4], and Lundsdaine[5]) that the liberalization of engineering requires a need to address these alternative learning styles. While one might argue for better exposure to a greater breadth of curriculum, such an argument is not typically viable in a constrained engineering curriculum. Alternatively, one can also effectively argue that if one focuses on a more open ended curriculum that forces students to look at problems from multiple perspectives, one may be doing more harm that good. For example, a beautiful looking bridge (yellow) that fails to provide the structural support needed does no one any good. The challenge is trying to provide value added from alternative perspectives without losing proficiency in fundamental technical skills. Hence, designing a curriculum that addresses alternative learning styles is not enough. One has to simultaneously engage students so as to significantly increase critical or complex thinking skills.

Complex Thinking Skills

While industry talks about the need for a multi-disciplinary approach to creative problem solving and thinking outside of the box, one can effectively couch this in the form of cognitive development. Although a number of developmental models exist, one of the earliest models was developed by William Perry[6] while at Harvard University. Specifically, Dr. Perry observed that on a 9 point scale most students enter a university environment around level 3.4 and matriculate somewhere around 3.6, well below what is desired by industry as well as what other research shows as possible from a brain development perspective (King and Kitchener[7]).

Figure 2. Perry Model for Intellectual Growth

Regardless of the model used, what is surprising is that multiple studies across multiple institutions show that students make surprisingly little progress on the cognitive scale and it makes little difference if they are in engineering, liberal arts, business, or any other discipline (King and Kitchener[6], Astin[8,9], Daloz[10]). Karl Smith[11] and others suggest that more engaged pedagogies (cooperative learning, service learning, etc) are required.

Industrial Engineering adopted the Steps for Better Thinking model[12] shown below in Figure 3 as the developmental framework for developing and assessing cognitive development gains in engineering students.

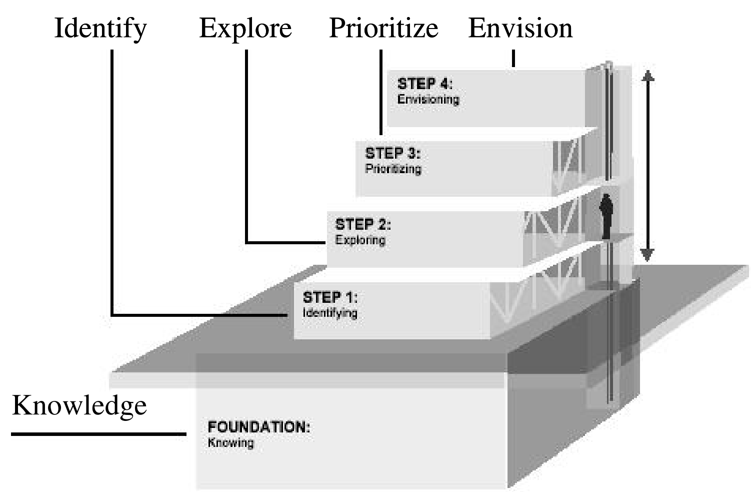


Figure 3. Steps for Better Thinking Model

Within the Steps for Better Thinking 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.

Value Added Curriculum

The South Dakota School of Mines and Technology has adopted a strategic initiative which includes a research and curricular component focused on economic development and entrepreneurship. Although industrial engineering has offered business, management, and entrepreneurial coursework since its inception in 1989, participation by non-majors was limited. A statewide entrepreneurship minor initiated in 2003 and offered through the Regental system received little positive response in terms of student participation. It did, however, highlight several significant principles that need to be met in order to better serve the needs of engineering students. Specifically, a value added curriculum should

- make use of existing curricular components to the maximum extent possible,
- be modularized to provide the smallest credit unit that is logistically feasible, and
- make use of alternative delivery mechanisms that allow for greater student flexibility.

To meet these criteria, the department revitalized and modularized a course in accounting and cost estimating, and reorganized the entrepreneurship course into five one-credit modules. By incorporating existing coursework, students can complete a certificate in Engineering Management or in Technology Innovation through coursework offered in mechanical, electrical, industrial, or mining engineering. Features of the program include the following.

- ***Flexibility*** – students can incorporate up to three credits through existing coursework taken within their major or they can complete the entire certificate through flexible offerings through the industrial engineering department. In depth offerings in financial analysis, marketing, organization, and intellectual property may be completed through existing coursework offered through the Regental system.
- ***Modularization*** – with the exception of product development which is two credits, all required coursework is available in one credit units of instruction.
- ***Modes of Delivery*** – Online material and multi-media design will eventually allow skills courses such as financial analysis and budgeting to be completed through alternative modes of delivery including an independent study option. Courses requiring simulations, casework, and open-ended discussion are being restructured to incorporate an inverted classroom approach.
- ***Diversity*** – The Engineering Management certificate has a managerial or Brownfield technology focus. Consequently, classroom activities and curriculum tends to have a slight shift towards individuals with a stronger task orientation. The Technology Innovation certificate program has an entrepreneurial or Greenfield technology focus. Classroom activities and curriculum tends to have more of a creative or innovation focus. Industrial Engineering students as well students in either certificate program are required to receive an introduction to team development processes and to the Herrmann Whole Brain model.

Inverted Classroom

One of the challenges facing educators is providing an appropriate balance between breadth and depth of coverage while simultaneously providing meaningful classroom experiential activities that engage students at a deeper level. This challenge is magnified even further when coupled with the modular approach needed to meet the student flexibility requirements to create a value added opportunity. One possibility of meeting this challenge, at least in part, is through the use of the inverted classroom. An "inverted classroom" is an instructional environment that mixes the use of technology with hands-on activities[13].

For the value added certificate programs, the inverted classroom is utilized in two ways. Traditional inversion requires that students complete reading assignments before class. Material includes basic multi-media reading assignments coupled with podcasts (see for example, Stanford Technology Ventures Program[14]) or interactive support exercises. Classroom time may then be devoted to case discussions or group problem solving exercises. Critical to this approach is utilization of the online quiz to ensure adequate student preparation prior to class. Foundational support for the knowledge base (see Figure 3) is provided through the online text and interactive exercises. Classroom activities attempt to focus on higher level thinking skills that require students to view problems from multiple perspectives. Figure 4 below illustrates a portion of the online text for the cost estimating course.

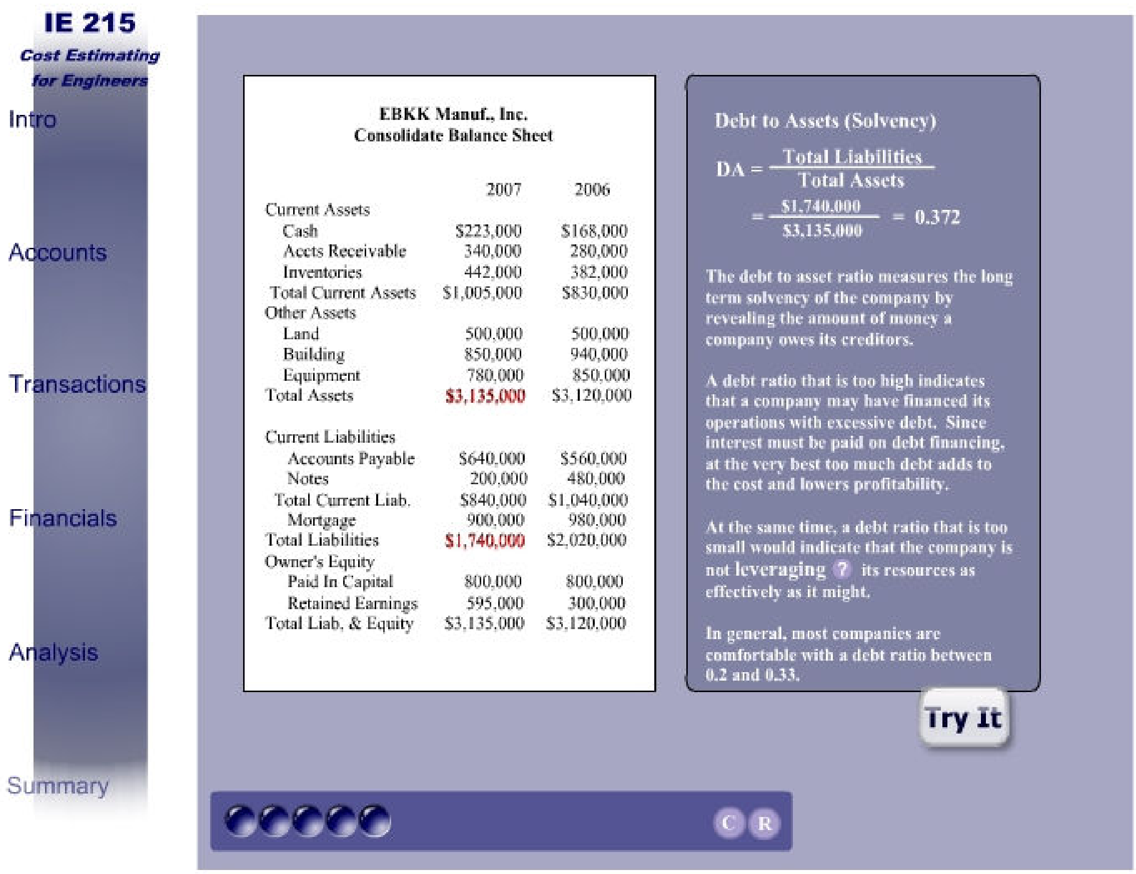


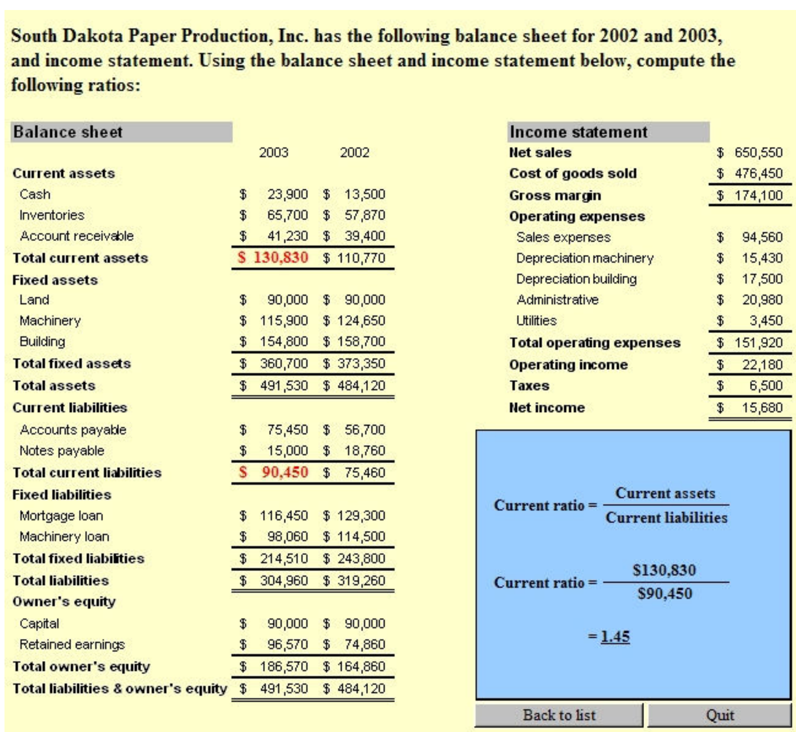
Figure 4. Portion of the Online Text for Cost Estimating

Each self-contained module provides a fully accessible navigation bar, reference material, help dialogue boxes for terms that may require additional information, and embedded supplementary exercises to provide foundational support at the knowledge level.

A second application the inverted classroom involves the use of supplemental material through technology enabled support modules. These modules are designed to be self-contained and provide a basis for student support for the foundational skills or the knowledge base in the Steps for Better Thinking model (Figure 3). All online interactions are self-correcting and may be accessed either through the online text or through student support pages found on the department home page. Support modules in the area of finance include loan calculations, wealth building, economic valuation, financial statements and analysis, process costing, personal finance, and supplementary self-readiness quizzes. The following section provides a short overview of a technology enabled support module.

Technology Enabled Support

The example shown below in Figure 5, 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 some modules promote a more conceptual framework of a body of material, 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

$$\text{Current ratio} = \frac{\text{Current assets}}{\text{Current liabilities}}$$

$$\text{Current ratio} = \frac{\$130{,}830}{\$90{,}450}$$

$$= \underline{1.45}$$

Back to list | Quit

Figure 5. Online Interactive Exercise in Financial Analysis

A second example shown below in Figure 6 demonstrates an online self-readiness quiz. By coupling to an external read/write file, the quiz module can also be adapted to provide an alternative to a quiz module in a course management application. A distinct advantage of technology support modules is that support modules may be modified for alternative learning styles.

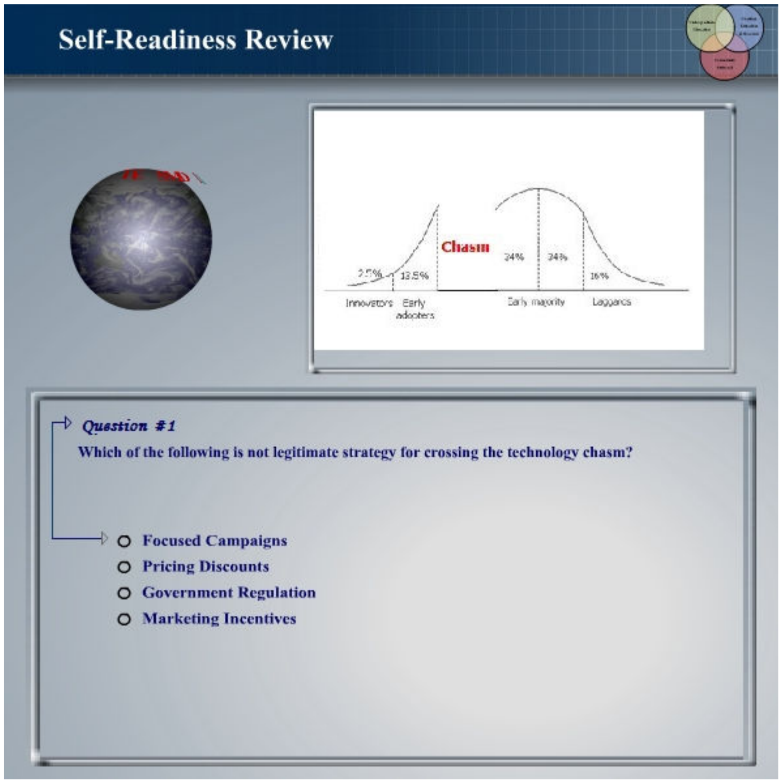


Figure 6. Online Self-Readiness Quiz Module

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 7.

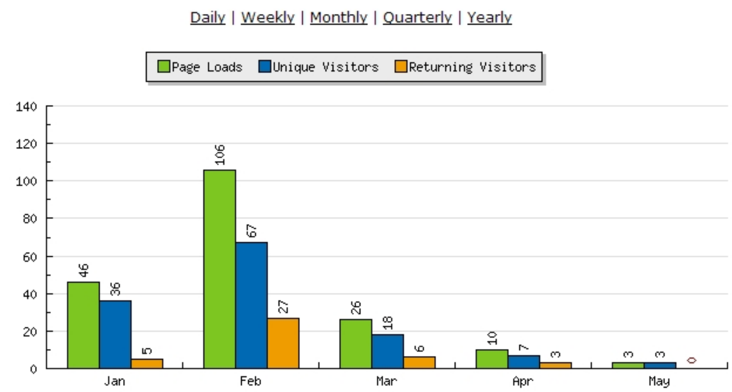


Figure 7. Page Loads, Unique Visitors, and Returning Visitors for Finance

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 8 shows the duration of a site visit for the financial web site. While it is clear that many students do not take advantage of the online support, it is also clear that a significant number of students spend considerable time with a number of the review modules. The most recent activity indicates that nearly 23% of the students spend a significant amount of time at the site reviewing material presented in one or more modules.

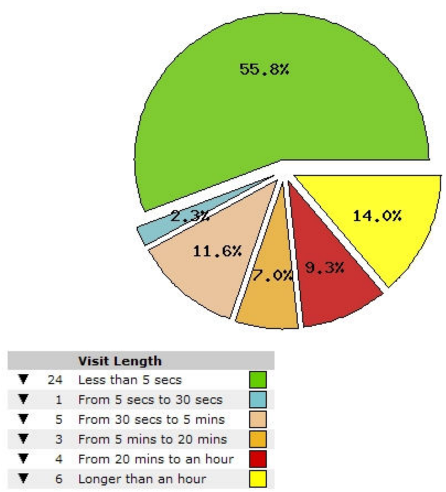
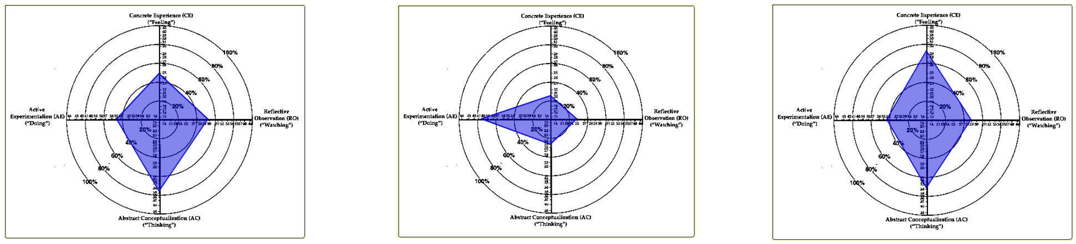


Figure 8. Visit Length for Finance Web Site

Of greater interest to the faculty is whether or not the programmatic and curricular modifications have had an impact on better serving diverse learners or have resulted in improved complex thinking skills. Six years data on student typology indicates that the average thinking preference curve for senior industrial engineering students looks remarkably similar to that of first year students[15]. Kolb learning preference curves have been tracked for industrial engineering majors for the past six years and compared to those of first year students. Results in Figure 9 below indicate that industrial engineering students have a tendency to retain a more balanced "kite" desired by industry.



(a) Engineering Freshman (b) Engineering Seniors (c) IE Seniors

Figure 9 LSI Comparison for Engineering Freshman, Typical Engineering Graduates, and IE Graduates

Interpretation of Figure 9 requires two stipulations. While the research supports a highly skewed average learning kite for senior engineering students, sufficient data does not yet exist for majors other than engineering. That is, Figure 9 (b) is a projection based on the literature only and is used here for demonstration purposes. Figure 9 (a) is based on baseline data of nearly 500 first year students in 2004 and 2005. Figure 9 (c) is based on data collected on 120 industrial engineering seniors from 2000 – 2006. The second stipulation is that the Kolb, while useful, is not particularly reliable and the department adopted the HBDI in 2007 for typological assessments. This was done for two reasons. The first is that the instrument is reliable and has both internal and external validity. The second, and more important reason, is that the model lends itself to a more holistic approach to open ended problem solving, which, in turn should help to promote more complex thinking skills.

A second objective of the program is increase creative and complex problem solving skills as measured through gains in cognitive development. The department has had over 70 hours of training on the steps for better thinking model. Student work is scored using the Steps for Better Thinking Rubric[12] and preliminary data suggests that students are gradually making cognitive gains. Baseline data utilizing the Reflections on Current Issues[16] (RCI) instrument was collected in 2006 as a means of supporting these claims, but there is not yet enough data to make cross department comparisons or even solid comparisons against national averages listed in the literature. Students have responded positively to the value added components and the department has experienced an average enrollment growth of over 8% over the last five years.

Conclusions and Future Work

The Industrial Engineering department embarked on an ambitious transformative approach to address diverse learning needs while simultaneously engaging students at a deeper level of learning. Data consistently shows that we have been remarkably successful, at least in the area of student diversity. A portion of this work is focused on providing value added opportunities for non-majors through increased modularization of content while simultaneously providing hands-on activities through an inverted classroom approach. While considerable work remains for a fully integrated inverted classroom approach, preliminary data suggests that such an approach can address diverse learning typologies and simultaneously engage the students at a deeper level. Ultimately, we envision an online resource that provides full text with embedded multi-media interactions that transforms the static lecture oriented classroom environment to one that fully incorporates a variety of engaged pedagogies.

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