Developing the Complex Thinking Skills Required in Today’s Global Economy

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Abstract - With the advent of a global economy there is a need for students to have knowledge of international organizational behavior and management. Even more importantly, today’s rapidly changing business climate requires students to possess the more complex and creative thinking skills needed to operate in that environment. In this paper, we present a systematic approach to address these requirements. Curricular components center around experiential learning opportunities which include business plans, service learning, international case studies, and team based projects. Improved thinking skills are measured through systematic evaluation of student cognitive development. Diverse and more creative thinking skills are measured through longitudinal assessment of learning preference curves.

Index Terms: experiential learning, cognitive development, learning style, technology enabled learning

INTRODUCTION

Calls for greater accountability in higher education are becoming more strident than ever. In engineering, these discussions often take the form of value added learning. Prior to global competition, companies typically accepted a portion of the responsibility for student learning by investing anywhere from one to two years training new hires in the business, management, and specialized technical skills needed. More and more, companies are expecting engineering graduates to hit the ground running with better problem solving skills, better team processing skills, better communication skills, and a better understanding of the business/management skills needed for today’s global environment.

To address these concerns, the Industrial Engineering (IE) program at SDSM&T has embarked on a long-term effort to reshape the existing curricular components to build developmentally appropriate integrative threads in three discipline stems: manufacturing systems, business and management, and safety and ergonomics. Curricular elements of the threads include technology enabled learning, service learning, business plans, and enterprise team projects. Using the Steps for Better Thinking Model [1] 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.

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 typological development [2,3], others suggest that a curriculum focused on the social aspects of student learning may be more productive [4-6]. Still others suggest that focusing on students’ intellectual development can lead to significant learning gains [7,8].

The Industrial Engineering program seeks to increase student involvement through three distinct but overlapping developmental thrusts.

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

This idea is, of course, not new and is similar to the notion of diversity proposed by Felder and Brent [9].

Identity / Social Development

Alexander Astin [4] suggests that the more students are involved in both the academic and social aspects of collegiate life, the more they learn. An involved student is one who devotes a significant amount of time and energy to academics, spends much time on campus, participates in student organizations and activities and interacts often with faculty. Goodsell and Tinto [5], strong proponents of learning communities, stress that a student’s involvement in college life can affect persistence. Further, persistence is greatest when students are involved both academically and socially. Traditionally, identity development is accomplished primarily through residence life and student support personnel by providing programming that follows Chickering’s [6] seven vectors of development that 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.

Typological Development

Typological development suggests that individuals tend to have different strengths and ways of solving more complex problems. While typological models are often characterized as learning preference curves, the primary impetus for considering typological development is to help students identify and strengthen areas of weakness in the problem solving cycle. Typological models commonly used include the Meyers-Briggs Type Indicator (MBTI) [10], the Visual, Aural, Read/Write and Kinesthetic Learning Style Inventory (VARK) [11], the Index of Learning Styles [9], and Kolb’s Experiential Learning model [12].

While industry tends to desire a more balanced learning preference curve that is typically found in engineering freshmen (Figure 1.a.), the traditional engineering curriculum often tends to support students with a stronger preference for active experimentation (Figure 1.b.). As a result, students with a stronger preference for reflective observation tend to be discouraged from continuing in an engineering curriculum.

![Typological Development Diagram](image)

**FIGURE 1**  
AVERAGE LEARNING PREFERENCE CURVES FOR ENGINEERING STUDENTS

Intellectual Development

Much of the current work in developmental theory originated with William Perry [13] from studies of students at Harvard University in the early 1960s. Perry observed that two students with nearly identical intellectual capacity may in fact differ markedly in their ability to effectively solve problems and engage in intellectual discourse. Work by King and Kitchener [14] suggests that student developmental growth occurs when experiential learning opportunities require reflective observation and judgment in well-defined stages.

Regardless of the model used, 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. Consider, for example, a conceptual model given by Daloz [15] shown in Figure 2 below.

![Developmental Model for Student Growth](image)

**FIGURE 2**  
DEVELOPMENTAL MODEL FOR STUDENT GROWTH

According to Daloz, 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.

A more recent model, Steps for Better Thinking [1] (Figure 3), provides a useful conceptual framework for that balance between challenge and support by providing appropriate strategies for helping students transition from one developmental stage to the next.

![Steps for Better Thinking Model](image)

**FIGURE 3**  
STEPS FOR BETTER THINKING MODEL

Conceptually, 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. The remainder of this paper discusses some of the developmental threads incorporated in the Industrial Engineering curriculum. We then follow with a discussion of preliminary assessment results obtained and close with a short discussion of proposed changes.
DEVELOPMENTAL THREADS

Knowledge/Foundational Base

Like many universities, SDSM&T is concerned with retention of students who, although capable, may require additional help or alternative instructional approaches. The industrial engineering program has embarked on a long-term process to incorporate a number of developmentally appropriate experiential learning opportunities throughout the curriculum. Review modules help to provide some of the scaffolding necessary for the foundational knowledge base.

A variety of review modules have been developed in a number of disciplines and are posted directly to the online course syllabi on an as needed basis. In addition, all modules are currently accessible from the industrial engineering program web page and are organized under topical areas of coverage. All pages are available to all students on campus. A summary of the review sites and sample modules are included in Table 1 below.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>REVIEW PAGES AND SAMPLE SUPPORT MODULES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob/Statistics:</td>
<td><a href="http://ie.sdsmt.edu/probweb/prob.html">http://ie.sdsmt.edu/probweb/prob.html</a></td>
</tr>
<tr>
<td>Central Limit Theorem</td>
<td>Variety of interactive demonstrations of CLT. Includes both intellectual and typological differences</td>
</tr>
<tr>
<td>Memoryless Property (Exp)</td>
<td>Interactive derivation of the memoryless property</td>
</tr>
<tr>
<td>Probability Distributions</td>
<td>Flash plots and summary information of 9 continuous distributions</td>
</tr>
<tr>
<td>Maximum Likelihood Estimator</td>
<td>Explanation of point and interval estimates as well as MLE estimates. Downloaded MLE software available</td>
</tr>
<tr>
<td>Operations Research:</td>
<td><a href="http://ie.sdsmt.edu/orweb/or.html">http://ie.sdsmt.edu/orweb/or.html</a></td>
</tr>
<tr>
<td>Linear Programming</td>
<td>Interactive development of a prototype model, demonstration of graphical solution, and sensitivity analysis</td>
</tr>
<tr>
<td>Finance:</td>
<td><a href="http://ie.sdsmt.edu/finance/finance.html">http://ie.sdsmt.edu/finance/finance.html</a></td>
</tr>
<tr>
<td>Loan Calculator</td>
<td>Loan calculator and loan schedule template</td>
</tr>
<tr>
<td>Wealth Accumulator</td>
<td>Flash plots and interactive exercises demonstrate accumulated wealth on both a before and after inflationary consideration. Retirement template included</td>
</tr>
<tr>
<td>Financial Analysis</td>
<td>Interactive problems demonstrate financial statements and analysis of financial health of organization</td>
</tr>
<tr>
<td>Functions:</td>
<td><a href="http://ie.sdsmt.edu/functions/functions.html">http://ie.sdsmt.edu/functions/functions.html</a></td>
</tr>
<tr>
<td>Functions</td>
<td>Flash plots and supplementary information for a number of first year functions</td>
</tr>
</tbody>
</table>

Explore

Student exploration begins with the GES engineering and science curriculum for first year students. The GES curriculum includes group activities, hands on experiments, and culminates in a two to three week team project [16]. Exploration activities are threaded in Industrial Engineering through laboratory activities in Work Methods and Measurement, Human Factors/Ergonomics, Operational Strategies, and Computer Controlled Manufacturing. Virtual simulations related to business strategies are included in engineering economics. Case studies and ethical dilemmas are written to try to solicit higher level responses in the Steps for Better Thinking model.

Prioritize/Envision

Prioritization and envisioning skills are developed through case studies in Management Processes and Entrepreneurship. These skills are further developed through service learning and capstone design projects. Currently service learning is included as part of the laboratory component in Work Methods and Measurement and Ergonomics/Human Factors Engineering. The Entrepreneurship course and seminar series culminates in a team-developed business plan for a new product or company. All capstone design projects are community-based service learning projects or enterprise team projects.

Service Learning

Service learning is the academically-based application of classroom principles to solve real problems within the community. A special case of problem-based learning, service learning provides a mechanism for students to participate fully in their learning. The students experience the entire problem solving process as they accomplish the goal set out by a sponsoring organization. Service learning projects often have the added dimension of full participation in the definition stage of problem solving and incorporate the entirety of Kolb’s Experiential Learning model. Service learning projects challenge the students to hone their communications skills, to work cooperatively with other disciplines and team members, and to understand the societal context in which their solution is to be implemented.

Service learning projects are included as part of the formal laboratory component in Work Methods and Measurement, Safety Engineering, Ergonomics/Human Factors Engineering, and the capstone design sequence. Additional opportunities are planned for Industrial Hygiene, Facilities Planning, and Entrepreneurship.

DISCIPLINE/CURRICULUM STEMS

The Industrial Engineering curriculum is gradually being re-organized along three primary discipline threads:

**Manufacturing Systems**

Nearly half of all Industrial Engineering graduates from SDSM&T begin their careers in some form of manufacturing, considerably higher than the national average. Currently, the students are required to take 15 credits of manufacturing-related courses, including production and operations management, facilities planning, statistical quality and process control, and computer-controlled manufacturing systems and robotics. In addition, Operational Strategies, which introduces the students to Lean Manufacturing and Six Sigma may be taken as an elective offering. In response to industry needs, a Six Sigma Greenbelt Certification program has been developed and is available to industrial engineering students as well as students from all of the other disciplines at SDSM&T.

The manufacturing systems curriculum is being redesigned to better demonstrate the links between the parts of the overall system. Greater emphasis is being placed on real world applications, both as classroom examples and in team-based projects. Team-based projects include service learning and enterprise team alternatives. Additionally, a new laboratory course is being developed to place the engineering design concepts in the context of workplace social situations. In this course, students will have the opportunity to view engineering decisions and the process by which they are made from the perspectives of labor and management/engineering.

**Business/Management**

Industrial Engineering students at SDSM&T complete 13 credits of business/management courses that include accounting, engineering economics, management processes, and entrepreneurship. VenturSim, a virtual business strategies application is incorporated in engineering economics and requires student teams to develop realistic strategies for a fictitious company. Management Processes incorporates ethical dilemmas and case work in strategic planning and marketing for international corporations. The entrepreneurship course requires student teams to formulate a complete business plan for a new product or company.

Technology enabled components includes modules on financial statements and analysis and wealth development. Planned modules include resources for business plan development and marketing. Additionally, the web site will include resources on venture capital, business plans, marketing, and to the National Collegiate Inventors & Innovators Alliance (NCIIA).

**Safety and Ergonomics**

Companies and organizations are increasingly interested in protecting the safety and health of their workers for humanitarian reasons, for regulatory reasons, and perhaps most significantly, for economic reasons. An NCEES (National Council of Examiners for Engineering and Surveying) survey indicated that nearly all engineering disciplines included significant responsibilities for safety. In addition, ABET requires that safety is one of the design elements that should be considered in the capstone experience. Tragically, most engineering curriculums do not include safety and health courses.

In recognition of the importance of these issues and as a response to industry requests, Industrial Engineering has introduced a minor in Occupational Safety. The minor requires a minimum of 21 credits from a list of required courses, which includes a minimum of six elective credits. The core requirements include Safety Engineering, Ergonomics / Human Factors Engineering, and Industrial Hygiene. In addition, students must choose either Industrial Psychology or Environmental Law and Policy and must complete a capstone project that contains a significant safety component. While Industrial Engineering students need not take advantage of the minor, they are required to take up to 12 credits of safety and ergonomics courses that include courses in Work Methods and Measurement, Ergonomics/Human Factors Engineering, Industrial Hygiene, and Safety Engineering.

**ASSESSMENTS**

Re-engineering the industrial engineering curriculum has two primary purposes: (1) to increase both the number of pathways through the curriculum and the level of supplementary support necessary to meet the needs of all our students and (2) to increase the developmental scaffolding and experiential learning opportunities necessary to develop more complex thinking skills in students. Assessments related to these two goals include tracking enrollment/matriculation data, assessing changes in typology from the freshman to the senior year, assessing learning and studying strategies, tracking student use of technology enabled learning modules, and assessing attitudinal changes as students’ progress through the curriculum.

Enrollment and matriculation data is shown below in Figure 4. Over the past five years IE has seen a steady growth rate of 10-12% per year with an overall matriculation rate of nearly 84%.

![IE Enrollment History](image-url)
Of some concern to the program faculty was the observation that the relative percentage of women seemed to decline over time. Currently, 26% of the Industrial Engineering students are women. This represents a significant change from 1999 when almost half of the Industrial Engineering students were women. Gender enrollment data collected since 1999 (Figure 5) indicates that while enrollment in the program by women has remained relatively constant, enrollment by the male population has increased substantially.

One possible explanation for the growth trend and the retention of a more diverse population of students is the increased level and variety of scaffolding afforded the IE students. This conjecture is supported through typological assessment. Kolb learning preference curves have been tracked for industrial engineering majors for the past four years and compared to those of first year students. Results in Figure 6 below indicate that industrial engineering students have a tendency to retain a more balanced “kite” desired by industry.

A second goal of the curriculum realignment is to help students develop more complex thinking skills. Although IE faculty members have utilized the Measure of Intellectual Development (MID) for the Perry scale and the STEPS rubric for the Steps for Better Thinking model, use of these measures is labor intensive. Further, these measures require formal training and certification before they can be used effectively (IE faculty members are currently working on this certification). Alternatively, substitute measures may be obtained through the use of an attitudinal survey and a formal assessment of student gains in learning and studying strategies.

The University of Pittsburgh attitudinal survey [17] is utilized to determine student perceptions of their ability to use math and science to solve problems in engineering. The most recent data collected for 18 juniors and 10 seniors provides a measure of gains in student perceived abilities in primary outcomes specified for the IE curriculum (Figure 7).

Though not a true measure of cognitive development, learning and study habits are assessed through the Learning And Study Strategies Inventory (LASSI). The LASSI was developed as part of a research project at the University of Texas in the late 1990’s as a means of promoting student personal development. The LASSI is a 10-scale, 80-item assessment of students' awareness about and use of learning and study strategies related to skill, will and self-regulation components of strategic learning. Research has repeatedly demonstrated that these factors contribute significantly to success in college and that they can be learned or enhanced through educational interventions such as learning and study skills courses. Assessment results for industrial engineering majors in a required senior level course are shown below in Figure 8.

Session T4D

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review modules. To achieve some measure of usefulness of the review modules, the probability review site includes a statistical counter that tracks student use during the semester. During the Fall 2004 semester the probability site had a total of 60 unique visitors, 17 of whom returned to the site two or more times. During this same time period, 8% of the students visiting the site spent over an hour at the site. Another 11% spent from 5 minutes to an hour at the site.

A similar counter was embedded in the Functions review site. Approximately 67% of the 350 students enrolled in GES 115 visited the Functions site at some point during the Fall 2004 semester with the heaviest load occurring during the data analysis and cantilever beam experiment portions of the course. 26% of these visitors spent anywhere from 5 minutes to an hour at the site during any given sitting.

**FUTURE DIRECTIONS**

While the existing coursework provides the foundational skills necessary for students to understand business process decisions, it fails to make the strong connection between technology and innovation and entrepreneurship that is needed to function in today's global economy. Current plans call for partitioning the current 13 business/entrepreneurial credits into smaller one-credit modules and develop a much stronger link between innovation and entrepreneurship. Once completed the Business/Management stem will be renamed Tech Venture and will be modeled after the University of Maryland Invention to Venture program. It is anticipated that smaller credit modules will also be able to entice students from other disciplines that have a strong entrepreneurial interest. SIFE teams will provide a service learning component for area business and industry.

Initiatives planned for the Ergonomics and Safety stem include external funding support for students participating in the Occupational Safety minor and a Safety Research and Training Center. Undergraduate students participating in center projects would receive academic and practical training from the core and affiliated courses. Undergraduates would work closely with the Center faculty to provide training, audits, and research services for the university and the community (companies, organizations, individuals).

The manufacturing stem includes plans for an operational strategies laboratory as well as additional elective offerings in six sigma and lean manufacturing. There is a need to provide a greater breadth and depth of support modules that feature a feed forward component as well as a supplementary review component.

Finally, considerable work remains to develop additional scaffolding and developmentally appropriate threads to strengthen both the vertical and horizontal linkages within the curriculum. Additional training and assessment certification in the Steps for Better Thinking model is being sought.

**REFERENCES**


