#2005-719

Scaffolding, Learning Styles, and Web-based Tutorials

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Abstract

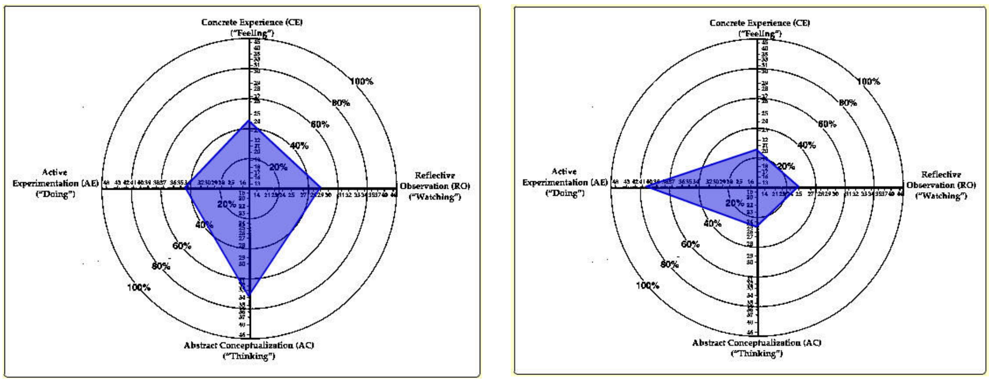
A growing body of research suggests that increased learning gains can be achieved when instruction is designed around an individual's learning style. Simultaneously, another body of research suggests that higher levels of thinking patterns can be achieved when instructional design uses a scaffolding approach. In order to help students develop more complex thinking skills one needs to provide a curriculum that is reasonably challenging while simultaneously providing the foundational support necessary for student success. 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.

Learning Style Preferences

A growing body of research suggests that students may enhance their performance academically with an understanding of the learning process[1-3]. In addition, a number of researchers suggest that a student's learning preference curve can be an effective predictor of student success[4-7]. Self-assessment of learning styles can be traced back to early personality tests developed during World War II. Personality types can be tested with the Meyers-Briggs Type Indicator (MBTI), which categorizes people into sixteen personality types[8]. Not only has the Myers-Briggs Type Indicator been utilized for work placement, it has also been used in the college classroom. There are, however, two significant drawbacks to the use of the Myers-Briggs inventory. It requires a certified professional to administer the inventory. Even then, researchers argue that it is more useful when used to indicate personality type than as a useful predictor of student learning preference style.

Neil Fleming and Charles C. Bonwell, with the hope of improving teaching and learning, created the VARK test in 1998[9-10]. The Visual, Aural, Read/Write and Kinesthetic Learning Style Inventory (VARK) classifies students based on how they process information presented to them. One advantage of the VARK Learning Style Inventory is that it can be taken online with an immediate assessment[11]. Those administrators interested in the VARK Learning Style Inventory without Internet access can request a teacher's guide and evaluation kit directly from the VARK Company.

In 1971, David A Kolb developed a Learning Style Inventory to assess individual learning styles[12]. This model categorizes people into four learning styles that relate to how they deal with ideas and daily situations. 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.



(a) For Engineering Freshmen (b) For Graduating Seniors

Figure 1. Average Learning Preference Curves for Engineering Freshmen and Graduating Seniors

The Kolb Learning Style Inventory is widely available and may be administered by anyone. For a modest fee, the Kolb Learning Style Inventory can be completed entirely online. Since it is specifically designed for assessing learning preferences, the Kolb Learning Style Inventory can be packaged with material that includes instructional and learning strategies for specific learning preferences. The Kolb Learning Style Inventory is perhaps the most widely used inventory currently in use in educational research.

Cognitive Development and Scaffolding

While some researchers focus on an adaptive curriculum based on a student's learning preference curve, others suggest that a curriculum focused on the developmental aspects of student learning may be more productive[13-16]. Better thinking and practical problem solving skills are embedded within the constructs of developmental theory. Indeed, many of the so-called "soft elements" in ABET criterion 3 (outcomes f, h, i, and j) are, in fact, embedded within this broader notion of cognitive development. Unfortunately, not only is cognitive development a difficult area to adequately assess, but, by its very nature, is a very difficult term to even adequately define.

Nevertheless, cognitive development has been an area of research for the past 40 years and a number of useful models have been developed. William Perry[17] developed a quantifiable measure of intellectual development from studies of students at Harvard University in the early 1960s. Perry's work originated from the observation 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. A number of researchers have built on Perry's work to account for gender and cultural differences. Work by King and Kitchener[18] 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 Dolaz[19] shown in Figure 2 below.

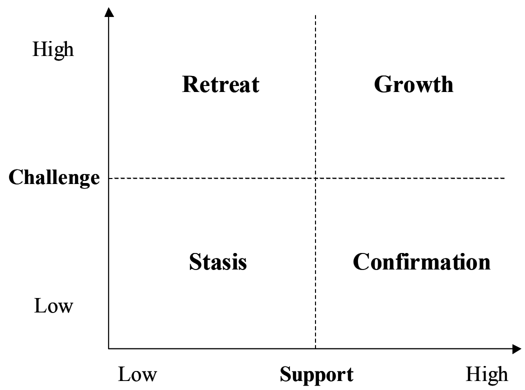


Figure 2. Developmental Model for Student Growth

According to Dolaz (Figure 2), if one wants students to grow developmentally, 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. Worse yet, students who encounter a challenging curriculum without having the support mechanisms necessary will actually retreat on the developmental scale.

Although developmental theory has strong implications for student learning, it is not always considered when looking at new instructional design. Creative or open-ended problems can be very effective but only when they are designed around the appropriate developmental stage of the learner. A more recent model, Steps for Better Thinking[20], provides a useful conceptual framework for developmental learning (see Figure 3 below) as well as providing appropriate curricular strategies for helping students' transition from one stage to the next.

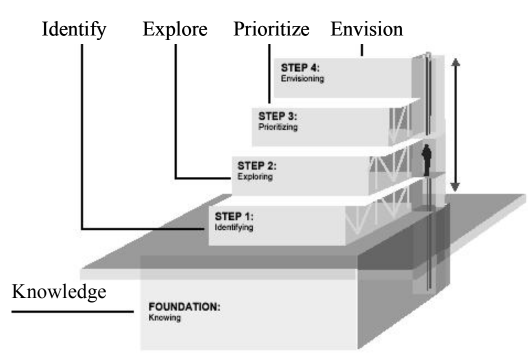


Figure 3. Steps for Better Thinking Model

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.

Web Based Tutorials

Recent work suggests that technology enabled learning modules can be effectively used to accommodate diverse learning styles[21-22]. Middle Tennessee State University even offers online versions of learning style inventories as a study skills aid to assist students in adapting to college academics[23]. In considering our support modules, we attempted to design knowledge modules that not only accommodate a variety of learning styles but also provide scaffolding that is developmentally consistent with the Steps for Better Thinking Model.

Consider for example, the concept of statistical reasoning. One of the problems identified from course assessments is that, for courses in industrial engineering, considerable time is spent reviewing probability or statistical fundamentals. By providing students with an opportunity for a focused review of basic concepts in probability and statistics, more class time can then be devoted to strengthening the relationship between statistical concepts and applications.

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

- 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.
- Where appropriate, modules should consider a variety of learning styles and developmental levels.
- Navigation through review modules should be student controlled.
- All materials should be developed for asynchronous mode.
- The mode of delivery must be technologically compatible at point of delivery. Download times, where applicable, must be kept to a minimum.

Consider an example module covering the central limit theorem. Explanation of the central limit theorem includes a formal definition of the theorem, experiential exercises demonstrating the theorem, a heuristic derivation, a formal derivation using moment generating functions, sample applications and an interactive problem solving exercise. Samples of the experiential exercises are shown in Figures 4 and 5 below. An example of the interactive heuristic derivation is shown in Figure 6.

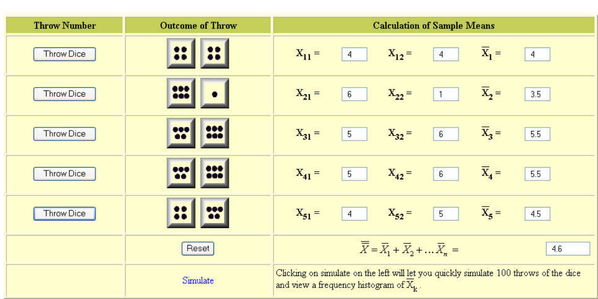


Figure 4. Demonstration of Central Limit Theorem; Dice Example

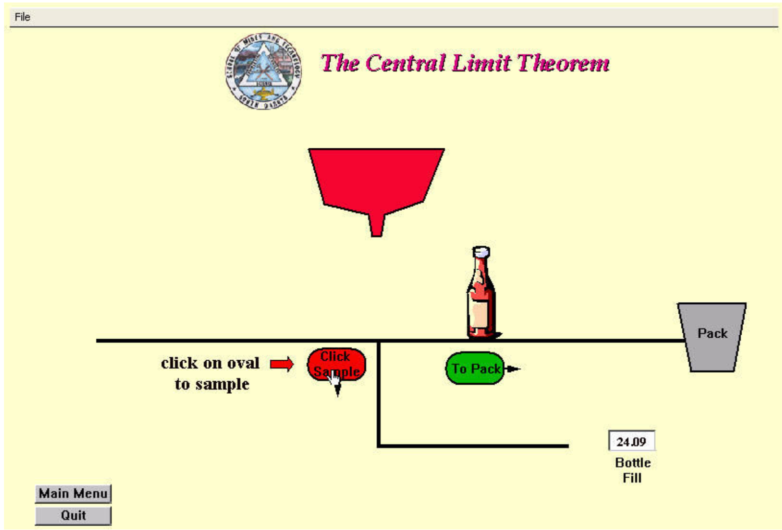


Figure 5. Demonstration of Central Limit Theorem; Manufacturing Simulation

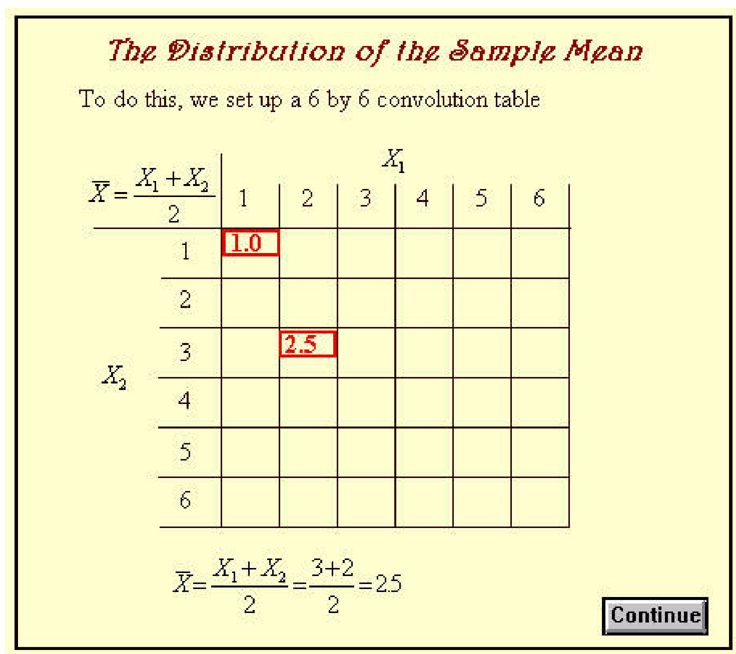


Figure 6. Interactive Heuristic Derivation of Central Limit Theorem

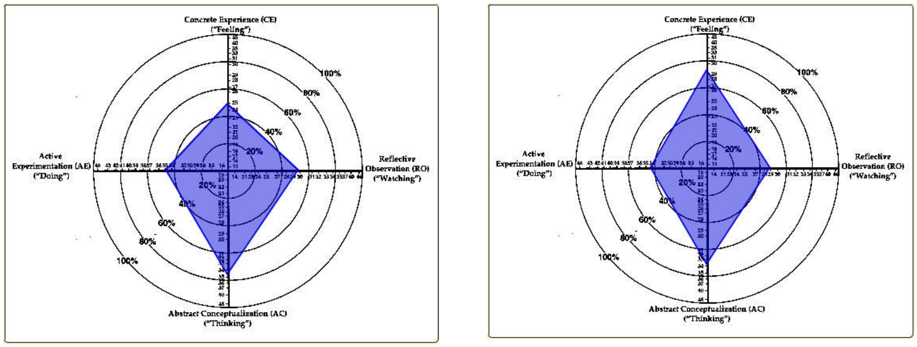
A variety of review modules have been developed in a number of disciplines and are posted directly to the online course syllabi on an as needed basis. In addition, all modules are currently accessible from the industrial program web page and are organized under topical areas of coverage. All pages are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

Table 1. Review Pages and Sample Support Modules

Probability and Statistics: http://ie.sdsmt.edu/probweb/prob.html	
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. Application problem is included.
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 user defined flash plots.
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 including the first order h-function as well as 3 options for goodness of fit tests.
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.
Finance: http://ie.sdsmt.edu/finance/finance.html	
Loan Calculator	Loan calculator and loan schedule template
Wealth Accumulator	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. Retirement template included.
Financial Analysis	Interactive problems demonstrate financial statements and analysis of financial health of organization.
Functions: http://ie.sdsmt.edu/functions/functions.htm	
Functions site is used primarily with first year students enrolled in GES 115. 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. The page also includes an interactive plot for a damped harmonic oscillator as well as 3-D parametric simulator.	
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.
Kolb	Included here for GES use. Kolb plots allow students to analyze individual learning preference curve based on Learning Style Inventory (LSI) scores as well as view averages for campus data by department, year of study, or by gender.

Preliminary Assessments

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. Kolb learning preference curves were tracked for industrial engineering majors and compared to entering freshmen. Results in Figure 7 below indicate that industrial engineering students have a tendency to retain a more balanced “kite” desired by industry.



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

Figure 7. Comparison of LSI Curve; IE Seniors to Entering Freshman

Although Figure 7 indicates that industrial engineering is achieving some success in retaining diverse learners, this may in fact be due more to experiential learning opportunities incorporated throughout the curriculum than to the 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. Results for the Fall 2004 semester are shown below in Figure 8. The plot includes page loads, unique visitors, and returning visitors. Peak use of the site roughly corresponds to review assignments included on the stochastic models online course syllabus.

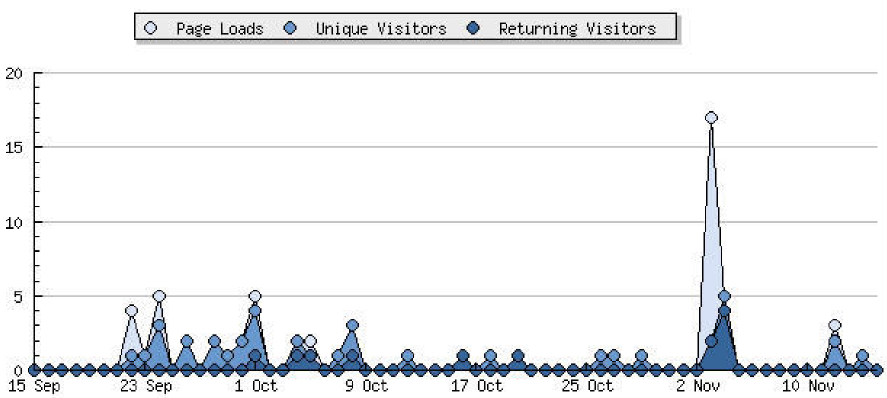


Figure 8. Plot of Student Usage of the Probability Review Site; Fall 2004

During the Fall 2004 semester the site had a total of 60 unique visitors, 17 of whom returned to the site two or more times. In addition to overall usage data, the statistical counter software allows a variety of additional information. The two most useful features include the ability to track popular page loads and time spent on site. The latter is particularly useful since it provides some indication as to the perceived usefulness of the site – the more useful the information the more likely a student will spend time at the site. 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.

Conclusions

Although considerable work remains to be done, preliminary assessments indicate that the review support modules do provide some level of support scaffolding for students. Although used primarily for just-in-time review, many of the support modules also provide application exercises and may thus be used in a feed forward manner. In addition to providing online review, most modules include an interactive demonstration of the topic, a sample interactive problem, and useful applications where the material may be applied. Although the development time is substantial, students seem more likely to propagate to sites that provide a variety of alternative approaches to the topic.

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