Session #3630

Effectiveness of Various Components in a Mechanics of Materials Course

David J. Mukai
University of Wyoming Civil and Architectural Engineering

Introduction

The pressures on undergraduate Science, Math, Engineering, and Technology (SME&T) education are well documented (1). Some of these problems include: undergraduate SME&T courses tend to filter out students, leaving only a few highly-qualified graduates; low retention in SME&T courses because students find them boring; and an increased amount of knowledge that needs to be transmitted. This project modifies materials developed by Gregory Miller at the University of Washington under the auspices of the NSF Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL) for implementation at the University of Wyoming. The original materials included standard homework and exams, design projects, group work, basic competency exams, computational visualization tools, multimedia instructional tools, hands-on experiences, and student presentations. The objectives and outcomes of this project are:

1. Adapt the engineering mechanics materials developed at the University of Washington and implement them into courses at the University of Wyoming
2. Evaluate the effectiveness of the adapted components at the University of Wyoming

Survey Class

In Spring 2002, the PI taught the targeted course, Mechanics of Materials, for his first time at the University of Wyoming without the materials being implemented from the University of Washington. Because of staffing issues, the PI did not teach the targeted course again until Spring 2003. The adapted materials were used in this class and evaluated by exit surveys and reflective notes. The students' preferred learning styles were determined by surveys.

The Spring 2003 class that used the new materials was comprised of 35 students. Administration of the course is at the college level and instructors for the course come from various departments and are rotated. Due to circumstances beyond the control of the PI, twelve of the students in the class were repeating the class. Course grades were based on fundamental exams, homework, hands-on activities, a course binder containing reflective comments, exams, and a final. These components are essentially the same as those described by Miller and Cooper (2).

Because of the very rural nature of Wyoming and the large in-state population of the University of Wyoming, a high percentage of students come from a "hands-on" background. To quantify this, students were given learning style surveys developed by Felder (3-6). In this survey, students are scored on a 1 to 11 scale in four attribute pairs. These a/b attribute pairs are: Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global. Active learners tend to process information while doing whereas reflective learners are more introspective. A sensing learner tends to focus on sensory information, and an intuitive learner focuses on intuitive information. A visual learner prefers pictures, diagrams, sketches, etc. A verbal learner prefers written and spoken words. Sequential learners learn one step at a time while global learners learn in a more comprehensive manner.

The results of these surveys are summarized in Table 1. Scores of 9 to 11 are categorized as a strong preference, 5 to 7 as moderate preference and 1 to 3 as mild preference. Ideally, there should be no even scores, but because some students did not answer all the questions or gave multiple answers, there are a few even scores. In this case, the response is divided between two categories. Thus, an 8 is considered half strong preference and half moderate preference. The class was 73% active, 76% sensing, 97% visual (with 61% being strongly visual), and 58% sequential. The active, sensing, and visual preferences likely reflect the students "hands-on" background.

Table 1. Learning Styles

a/ b Pair:	Active / Reflective	Sensing / Intuitive	Visual / Verbal	Sequential / Global
Total a	*73%*	*76%*	*97%*	*58%*
Strong a	8%	21%	61%	9%
Moderate a	35%	30%	27%	18%
Mild a	30%	24%	9%	30%
Total b	*27%*	*24%*	*3%*	*42%*
Strong b	0%	0%	0%	3%
Moderate b	6%	12%	0%	9%
Mild b	21%	12%	3%	30%

Course Components

These components are essentially the same as those described by Miller and Cooper (2). They are briefly described below, and changes from Miller and Cooper are noted.

- Exams
  There were three one-hour exams. The survey was administered before the final exam, so the student responses do not include this exam.
- Fundamental Exams
  These four gateway exams covered fundamental concepts of the class: stress,

strain and Hooke's law, units, and beams. Students must pass these exams to pass the course. They are allowed to take these exams as many times as necessary to pass.

- Hands-on Experiences
  These varied from computer exercises to quick physical demonstrations of course concepts.

- Homework
  Homework was assigned weekly. The problems were typically standard problems from the textbook. On two occasions, students were given problems to solve using a spreadsheet.

- Reflective Homework Sheets
  Students kept a pictorial log of their homework problems and reflected on what they learned each week. Students filled out one sheet per week. On one side of a log sheet they made a small sketch of each homework problem and noted the main components of that problem. On the reverse side, the students wrote down what they learned that week and any questions they had from that week's material. These sheets were collected and returned weekly for formative purposes and collected for grading at the end of the semester.

- Multimedia Lectures
  Interactive material developed at the University of Washington were used to deliver lectures. These materials were developed in a card-based authoring environment. The original implementation was in Hypercard and efforts to port to a Windows-based card-authoring program are nearing completion. An example of the interactive nature of the software is constructing Mohr's Circles from a simulated experiment. A very detailed description of the material can be found in Miller and Cooper (2).

  Since these materials were developed to be used in an interactive lab setting, using them to deliver lectures was not the optimum implementation of these materials.

- Portable Computers
  Students were asked to rate the hardware only in this component. There were 15 wirelessly networked portables available for 35 students. The portables were typical middle of the line units equipped with an IEEE 802.11b (11Mb/sec) wireless card. This is the only major difference with Miller and Cooper's work (2).

- Dr. Stress Software
  This software is a three-dimensional visualization software for stress. Being a tensor, stress is difficult to visualize. This software helps the students see how the components of the stress tensor change with a three dimensional rotation of axes. Again, a detailed description of this software can be found Miller and Cooper (2).

Assessment Procedure

In addition to the students' coursework, a mixed-mode evaluation was made of the effectiveness of material. Students kept a weekly homework journal (qualitative) and at the end of the semester each student took an exit survey (quantitative) administered by the instructor. These components are discussed in detail below.

Coursework

The graded materials for the course consisted of fundamental exams, homework, hands-on activities, a course binder containing reflective comments, exams, and a final.

Each student was required to pass four fundamental exams to pass the course. As implied by the name, these gateway exams covered the fundamental concepts of the class. Students were required to get the exams completely correct, but were allowed to take the exams as many times as needed. Every student passed all four exams. Traditional text homework problems were assigned weekly and counted for 15% of the grade. In addition to this, students were required to keep a binder of their homework and weekly reflective summaries of their homework (see next item below). The binder was worth an additional 5% of their grade. There were several in-class hands-on activities during the semester. Participation in these activities was worth 10%. Three traditional one-hour exams (40%) and a comprehensive final (30%) made up the majority of the coursework.

Homework Sheets

Students were asked to keep weekly summaries of their homework. On the front side of the HW review sheets, the students were to make a sketch and write down notes of each assigned HW problem. On the backside of each sheet, the students were asked to summarize what they learned that week and to write down any questions they had on the material.

Exit Surveys

The bulk of the quantitative assessment data was taken during an exit survey administered by the PI/instructor. Students were asked to rate eight components of the course (described earlier) in four categories on a 1 to 5 scale.

The four categories that these components were rated in on a 1 to 5 scale were:

- How well did you like this component?
- How well did this component help you learn?
- How well did this component keep your interest in the course?
- How well did this component help you retain the material for this course?

After rating a component in these four categories, students were asked to comment on the component. The PI, who conducted the surveys, then followed up these comments with further questions that varied from student to student. After the students had gone through all eight components, they were then asked to rank the top three that helped them in the class. The survey interviews were conducted by the PI/instructor one student at a time and each lasted about 15 minutes.

Results

Learning, Liking, Retention, and Interest

To examine if there is any correlation among the survey categories, three tests were performed: a χ^2 test of independence, jitter plots, and a Spearman's rank-correlation coefficient.

A χ^2 test of the null hypothesis of independence was conducted on all pairs of answers. This was done by comparing the actual frequencies to the expected frequencies. The resulting χ^2 values are shown in Table 2. For each pair, there are 25 possible responses and 16 degrees of freedom. For 16 degrees of freedom, $\chi^2 = 34.3$ for a 0.005 probability of correlation. Since the resulting χ^2 values are much higher than this, the variables are not independent.

Table 2. Chi-squared Values

	Learn	**Interest**	**Retention**
Like	270.6	255.7	171.0
Learn		354.0	280.7
Interest			198.1

To confirm that the variables were not independent, jitter plots were constructed. A random number ranging from –0.05 to +0.05 was added to all the responses. This causes a high number of responses for a given pair to appear as a larger dot in the plot. The jitter plot for Learn Rating vs. Like Rating is shown in Figure 1. Plots for all other pairs are very similar.

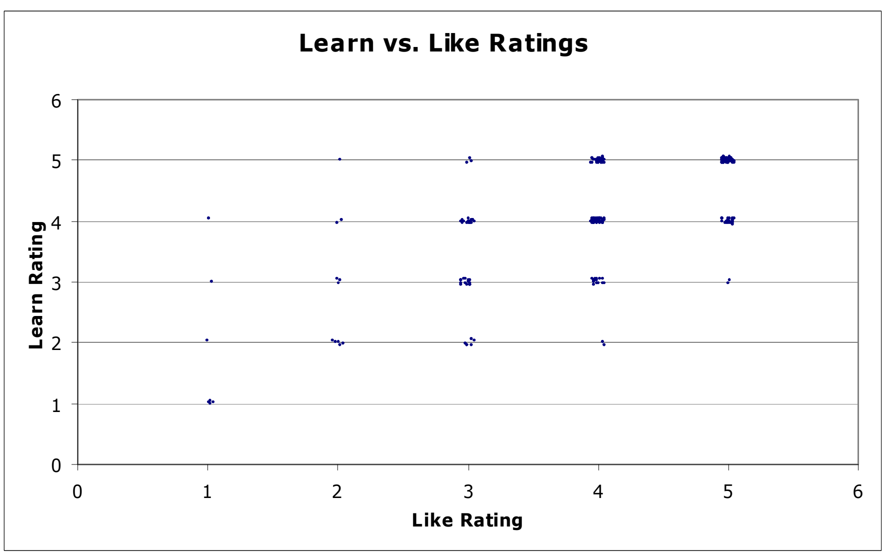

Figure 1. Learn Rating vs. Like Rating jitter plot.

To quantify the correlation among the category ranking, a Spearman's rank-correlation coefficient is calculated for all $\binom{n}{2}$ pairs of categories. This rank-correlation coefficient is given by (7):

$$r' = 1 - \frac{6\left(\sum d^2\right)}{n\left(n^2 - 1\right)}$$

where d = rank difference and n=number of samples

The Spearman rank coefficient for all pairs of survey categories are presented in Table 3 below.

Table 3. Spearman Rank Coefficients (r′)

	Learn	**Interest**	**Retention**
Like	0.660	0.733	0.542
Learn		0.682	0.708
Interest			0.582

Components

The exit survey results for each of the components are listed in Table 4 below. The same information for the Like rating is shown graphically in Figure 2. This figure presents the averages and 95% confidence intervals. Plots for the Learned, Interest, and Retention ratings are similar.

Table 4. Component Survey Results

Component	Liked	Learned	Interest	Retention
Exams	3.88 / 0.65	3.94 / 0.83	3.55 / 0.71	4.09 / 0.95
Fundamental Exams	4.12 / 1.05	4.64 / 0.55	3.85 / 0.94	4.55 / 0.71
Hands-on Experiences	4.73 / 0.45	4.55 / 0.62	4.64 / 0.60	4.58 / 0.61
Homework	3.94 / 0.61	4.36 / 0.65	3.91 / 0.68	4.30 / 0.77
Reflective Homework Sheets	3.03 / 1.21	3.15 / 1.33	2.52 / 1.00	3.45 / 1.20
Multimedia Lectures	3.58 / 1.00	3.64 / 0.90	3.55 / 0.97	3.42 / 0.94
Portable Computers	4.47 / 0.72	4.34 / 0.60	4.41 / 0.67	3.88 / 0.91
Dr. Stress Software	4.52 / 0.57	4.28 / 0.96	4.31 / 0.89	4.03 / 0.87
All Components	4.02 / 0.97	4.11 / 0.97	3.83 / 1.02	4.04 / 0.97

Average response is listed first followed by standard deviation.

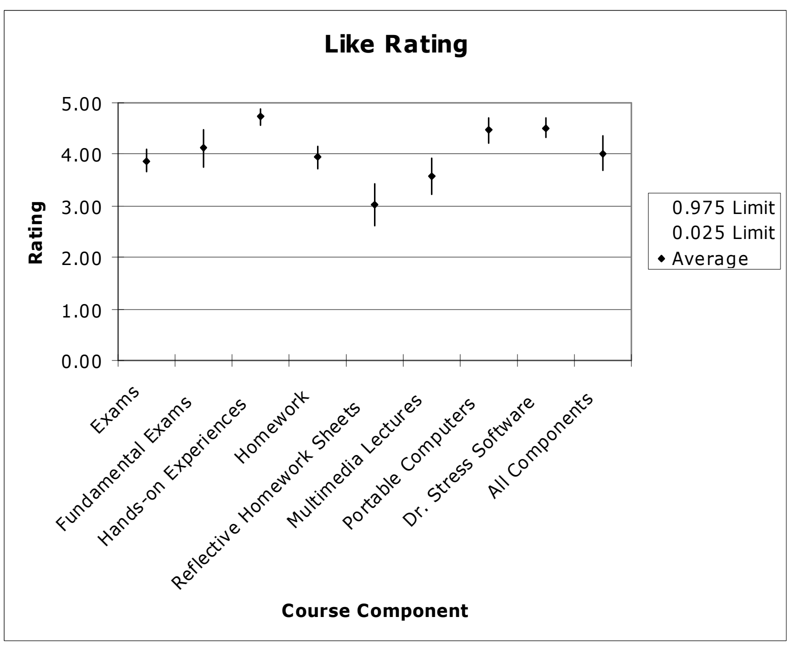

Figure 2. Like Rating by Component.

Components by First Time or Repeat Student

A comparison is made of the first time and repeating students in Figure 3. The average rating response of the repeating students is divided by the average response of the first time students.

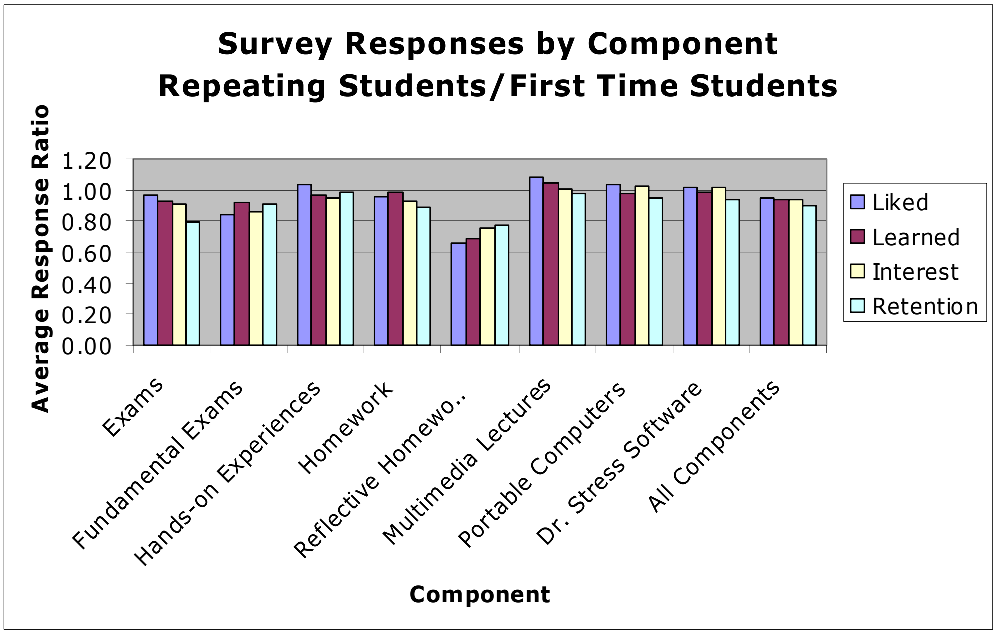

Figure 3. Ratio of survey responses of repeating students to first time students.

Components by Learning Style

To make the data more manageable, selected course components are compared to selected learning style dimension(s). The component and corresponding learning style dimension(s) are listed in Table 5 below.

Table 5. Course component and learning style dimension(s).

Component	Learning Style Dimension Examined
Hands-on Experiences	Active/Reflective Sensing/Intuitive Visual/Verbal
Reflective Homework Sheets	Active/Reflective
Multimedia Lectures	Visual/Verbal
Portable Computers	Active/Reflective
Dr. Stress Software	Active/Reflective Visual/Verbal

The ratings for the above combinations are presented in bubble graphs in Figures 4 to 11 below. In all these graphs, the y axis is the rating, the x axis is the learning style dimension, and the bubble size is the number of responses for the given rating. The number or responses are also listed next to the bubbles. Since the "like" category is correlated to the "interest" category and the "learn" category is correlated to the "retention" category, these pairs are averaged.

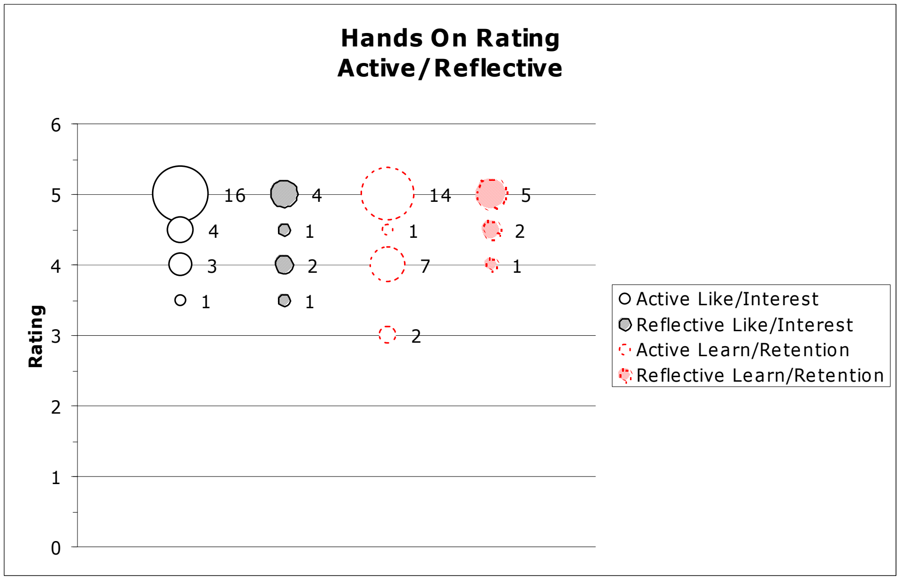

Figure 4. Hands-on component rating for Active/Reflective learning styles.

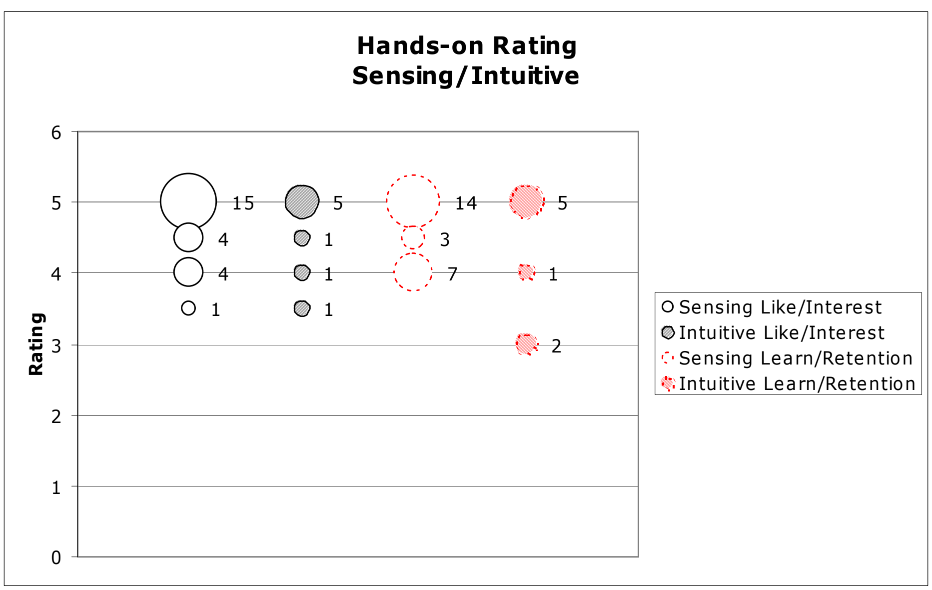

Figure 5. Hands-on component rating for Sensing/Intuitive learning styles.

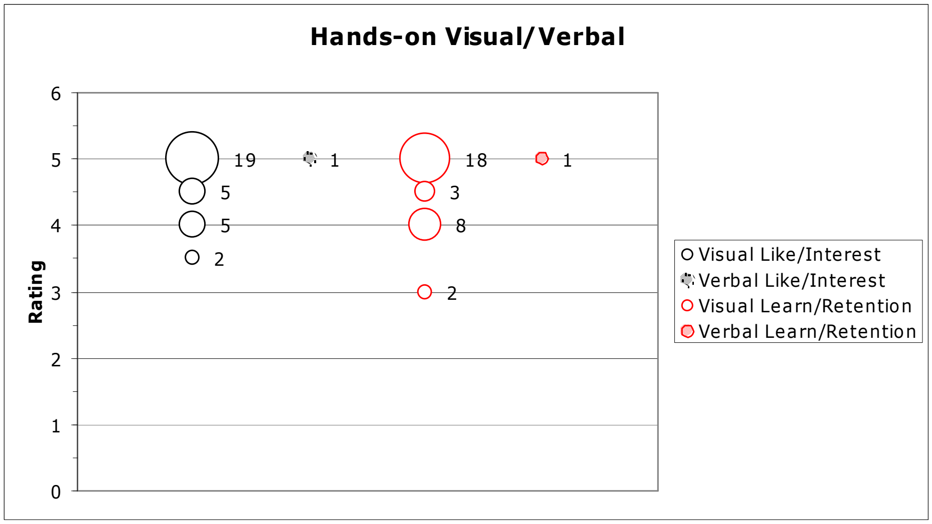

Figure 6. Hands-on component rating for Visual/Verbal learning styles.

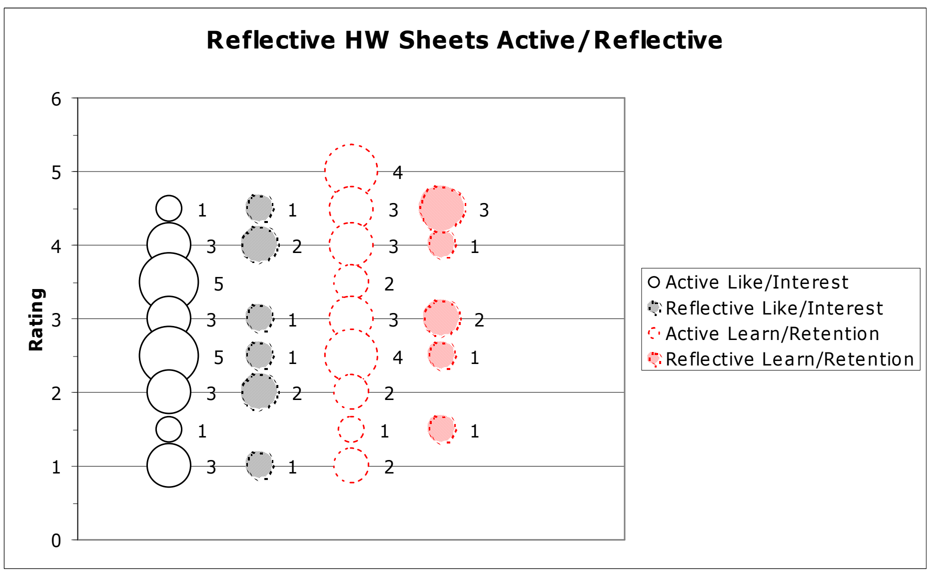

Figure 7. Reflective HW Sheets component rating for Active/Reflective learning styles.

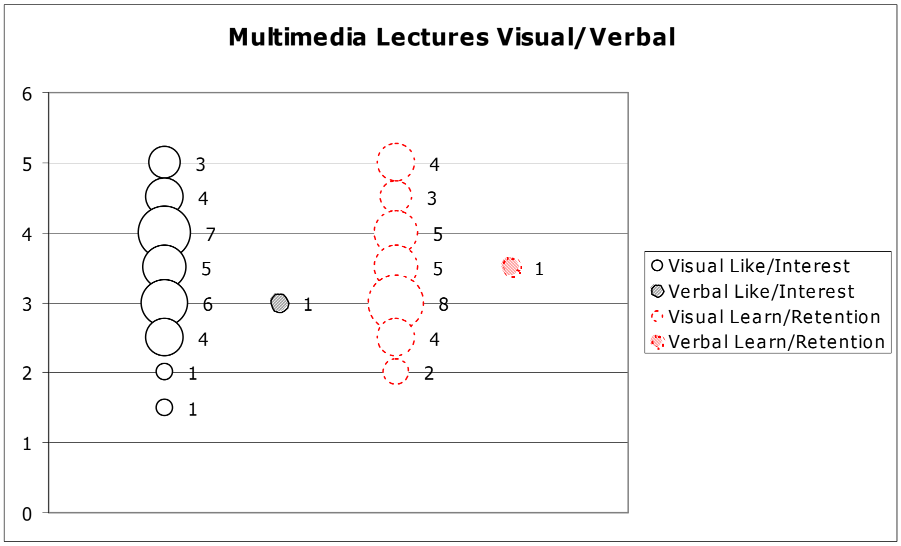

Figure 8. Multimedia lecture component rating for Visual/Verbal learning styles.

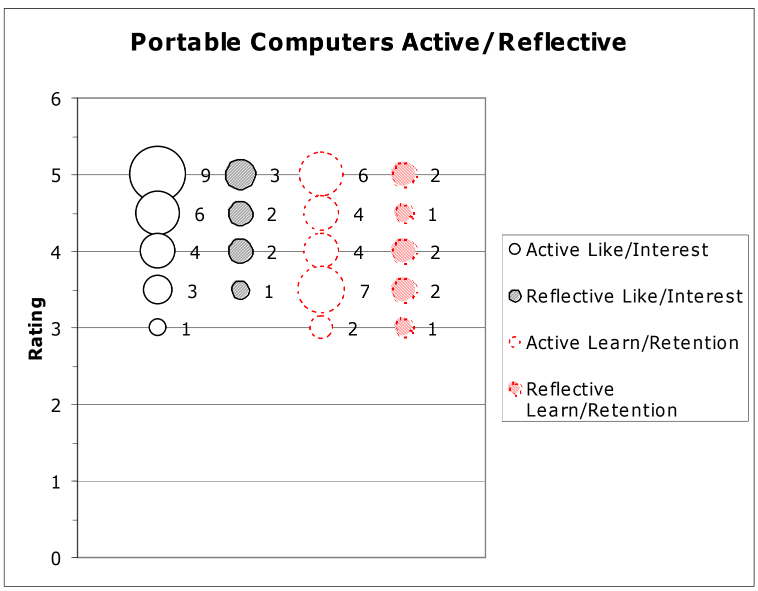

Figure 9. Portable Computers component rating for Active/Reflective learning styles.

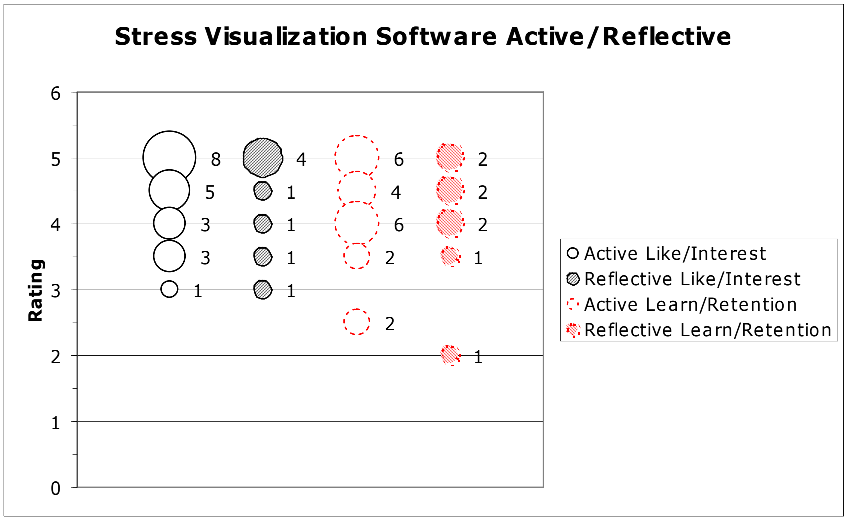

Figure 10. Stress Visualization Software component rating for Active/Reflective learning styles.

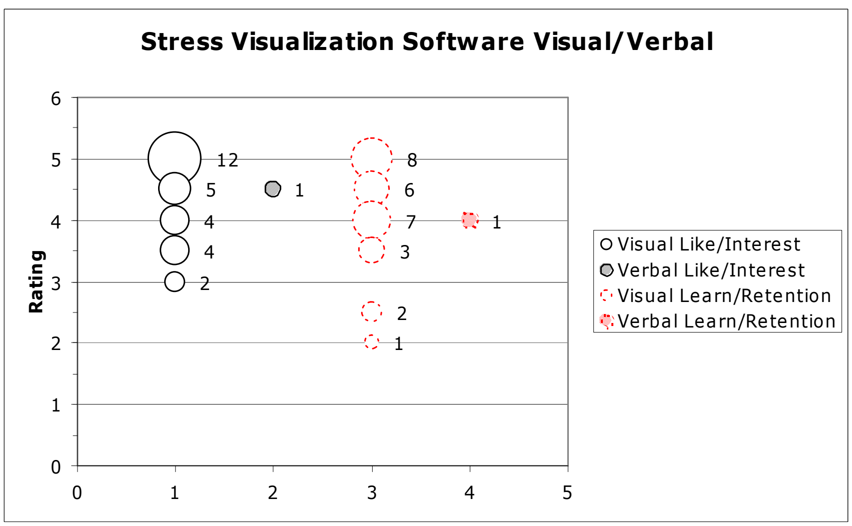

Figure 11. Stress Visualization Software component rating for Visual/Verbal learning styles.

Traditional Elements

The students' responses to the survey questions about exams and homework are compared to their exam and homework scores. The average exam score of respondents is sorted by response to survey questions on exams and homework in Figures 12 and 13.

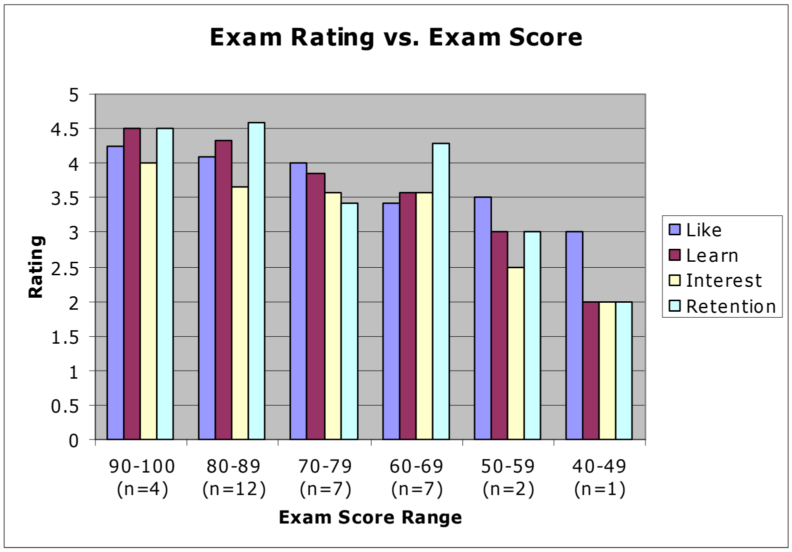

Figure 12. Exam Score Average vs. Survey Rating Response

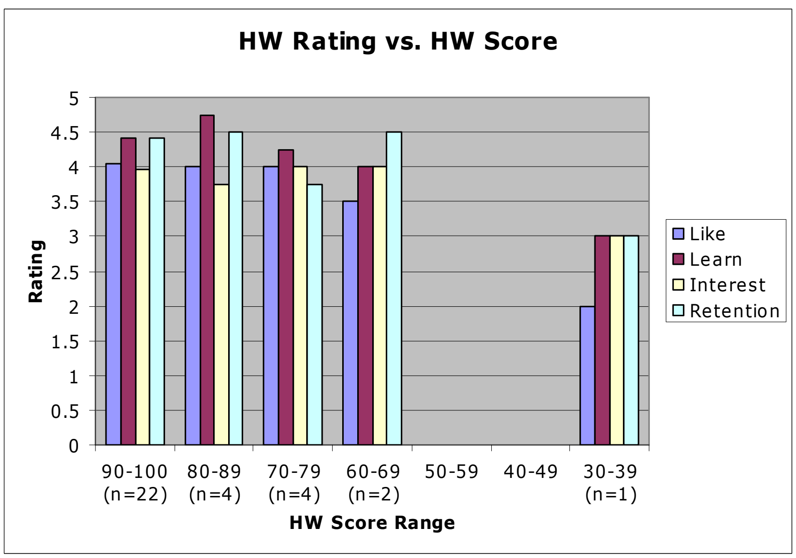

Figure 13. HW Score vs. Survey Rating Response

Pre/Post Comparison

As stated earlier, the measurement instrument was not given to the class that did not use the implemented materials (Spring 2002). Thus, the only basis for comparison is standard student evaluations. Also, there are many other factors that affect the two different classes:

- There is no record of how many students were repeating the class in Spring 2002
- The Spring 2002 course was taught in the PIs first year at the University of Wyoming – while he was still adjusting to a new environment

- In Spring 2002, the PI was an unknown to prospective students. This may have affected the type of student that registered for the PIs section of the class.
- In Spring 2003, efforts were renewed at the college level to bring consistency among the various section of this course. Small changes were made to the course content.

A comparison of student evaluation numbers between Spring 2002 and Spring 2003 (with and without the new materials) are shown in Table 6 below. Since lower numbers are better, a ratio less than one in the third column (Sp03/Sp 02) means the Spring 03 students rated an item higher than the Spring 02 students. While most of the ratings are the same, the Spring 03 students felt the quizzes were not as consistent with the materials covered, the homework was not as important, the text book was not as valuable, and the course handouts were not as valuable as did the Spring 02 students. All the ratings are relatively positive (low numbers) and thus small changes appear as large percentage changes. To gauge this, the fourth column normalizes the rating change over the 1-5 scale range, $\frac{\text{Spring 03} - \text{Spring 02}}{4}$. Using this measure of change, the most increased negatively viewed aspects of the course were the value of the text, the instructor's supplementary material, the quizzes' consistency with course material, instructor's office hours, and returning materials in a timely fashion. The largest increase in rating (which is a negatively viewed outcome) is 0.6 out of 4, or 15% of the score range. However, given the concerns mentioned above, it is difficult to ascertain if the difference is due to the materials or to external factors.

Table 6. Comparison of Teaching Evaluation of Course Taught with and without Materials. Scale: 1-5, Lower scores are better.

Item	Sp 02	Sp 03	Sp 03/Sp 02	(Sp 03 - Sp 02)/4
The instructor presents the course material clearly	1.9	1.8	0.95	-0.025
The instructor is knowledgeable about the subject	1.4	1.2	0.86	-0.050
The instructor is enthusiastic about the subject	1.3	1.4	1.08	0.025
The instructor makes students feel free to ask questions, disagree, express their ideas, etc.	1.5	1.5	1.00	0.000
The instructor is prepared for class	2.1	2	0.95	-0.025
The instructor is regularly available during scheduled office hours to provide assistance	1.7	2.2	1.29	0.125
The instructor is actively helpful when students have difficulty	1.5	1.7	1.13	0.050

The instructor stimulates critical thinking	1.7	1.9	1.12	0.050
The instructor uses good communication skills	1.6	1.8	1.13	0.050
The instructor returns graded materials in a timely fashion	2.4	2.8	1.17	0.100
The grading system is appropriate	1.6	1.9	1.19	0.075
The quizzes and exams are consistent with the material covered	1.5	1.9	1.27	0.100
The homework is important to your understanding of the course	1.4	1.7	1.21	0.075
The text is a valuable learning aid	2.3	2.9	1.26	0.150
Instructor supplied course materials are valuable learning aids	1.6	2.1	1.31	0.125
The course is well organized	2.1	2.1	1.00	0.000
Considering everything, how would you rate this instructor	1.8	1.8	1.00	0.000
Considering everything, how would you rate this course	2.3	2.4	1.04	0.025

Discussion

Learning, Liking, Retention, and Interest

The chi-square tests (Table 2) and the jitter plots (Figures 6-11) clearly show that learning, liking, retention, and interest are all inter-related. The Spearman rank correlation coefficients (Table 3) indicate that a component that is liked by the students is correlated to keeping the students' interest. Also the components that the student felt that helped them learn the most are correlated to components that helped them retain information.

Components

The hands-on experiments were the most liked component of the class. The students felt that the fundamental exams helped them learn the most. The hands-on experiments were the most effective at keeping the students interest. The fundamental exams and the hands-on experiments seemed to help the students retain information.

In all four categories of like, learn, interest, and retention, the reflective homework sheets and multimedia lectures were ranked significantly lower than other components of the course. The software that was used for presentation is actually designed for interactive hands-on use by the students and was not being used in the manner intended by the developers.

Effect of Learning Style

The reason for the varied components of the course is to address the various learning styles. Interestingly, many of the components designed for a particular learning style generated interest and learning across learning style boundaries. For example, both the active (hands-on) and reflective learners liked and learned from the hand-on activities (Figure 6). The same can be said about the sensing and intuitive learners. Since there was only one verbal learner in the class, no comparisons can be made between visual and verbal learners.

The reflective learners did not like or learn from the reflective homework sheets any more than the active learners (Figure 7). A qualitative analysis of the comments on the sheets is the subject of future work. Also, there did not seem to be much difference in response between active and reflective learners to the portable computers.

Traditional Elements

The students' rankings of the exams go down with exam score. There is no way to tell which is the cause and which is the effect. However, the data show that the students' ranking of the element corresponded to their performance. The results for the students' ranking of the homework are much different from the ranking of the exams. Except for the one student who did extremely poorly on the homework, the homework ranking is relatively constant over homework score. Extensive class time was used to help with homework, which resulted in the high number of high homework scores.

Conclusions

The following conclusions are based on the responses of one class of Mechanics of Materials at the University of Wyoming. The students in this class were mostly active, sensory learners and almost exclusively visual learners, with over 60% strongly preferring visual learning. Moreover, about one third of the class was repeating the class. For this set of students, the following conclusions are drawn:

- How well a student liked a component, how much the component kept the student interested in the course, how much the student felt the component helped her/him learn and retain the material are all inter-related.
- How much a student liked a component was most strongly correlated to how much the component kept her/him interested in the course.
- How much a student felt she/he learned from a component was most strongly correlated to how much she/he felt the component helped her/him retain the information.
- The hands-on experiments were the most liked, ranked the highest for keeping the students' interest, and were ranked highest for helping the students retain information.
- The fundamental exams were ranked highest for helping the students learn.
- The reflective homework sheets and the multi-media lectures were ranked the lowest in all categories.

- Components designed for a particular learning style were ranked similarly by the targeted learning style and the non-targeted learning style.
- A higher ranking of exams corresponded to a higher score on the exams.
- The ranking of the homework is relatively constant regardless of homework score.

Recommendations

The following follow up actions are recommended:

- Revise the survey instrument
- Repeat this study for a larger group of students
- Apply this study to a different set of learning styles

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Biographical Information

David J. Mukai is an Assistant Professor in Civil and Architectural Engineering at the University of Wyoming. His current research interests include Engineering education, heat-straightening repair of damaged steel, self-consolidating concrete, and fracture mechanics.