Session: FD3-1

SOME LEARNING ASSESSMENT METHODS FOR ENGINEERING COURSES

Ronald E. Barr
Mechanical Engineering Department
University of Texas at Austin
rbarr@mail.utexas.edu

Abstract

Engineering faculty is encouraged to pursue scholarly methods in teaching their courses. The recent past ASEE Year of Dialog (YOD) and the current NSF-sponsored project “Creating a Culture for Scholarly and Systematic Innovation in Engineering Education” both underscore the value of scholarship in engineering teaching. The new scholarship of engineering education has several important domains in which faculty must focus their attention: 1. What to teach; 2. How to teach it; 3. How students learn; and 4. How to assess it. While engineering faculty are quite adept at “What to teach” and perhaps “How to teach,” they are less aware of methods to determine “How students learn” and “How to assess it.” This paper presents several methods to assess learning in engineering courses, both quantitatively and qualitatively. These methods include pre- and post tests, outcomes assessment, affect surveys, and topics matrices. These methods are illustrated with actual assessment data gathered in a VaNTH biomechanics engineering course and verified by a replicated study in the same course three years later.

1. Introduction

In an effort to improve the national status of engineering education, faculty is encouraged to focus on educational research and scholarly teaching activities. Recent activities fostered by ASEE have promoted this focus on scholarship. During the 2006-2007 academic year, a Year-of-Dialog (YOD) was conducted at fourteen ASEE section and zone meetings with over an estimated 1,000 participants. The primary topic of discussion was on ways to improve the scholarship of engineering teaching. Results of the discussions were documented in a paper [1], and suggested that the key to improving scholarship was to recognize engineering faculty who do educational research and innovation in engineering teaching. A current NSF-supported ASEE project called “Creating a Culture for Scholarly and Systematic Innovation in Engineering Education [2]” aims at answering the fundamental question: “How do we create an environment in which many exciting, engaging, and empowering engineering educational innovations can flourish and make a significant difference in educating future engineers?

1.1 Scholarship of Engineering Education

Most all engineering faculty have a Ph.D. in an engineering discipline, and hence are inclined to perform research in their disciplinary field, and not dabble in educational research. Nonetheless, all engineering faculty are expected to teach engineering courses. Thus, it seems preferable to use the word **scholarship** in the place of the word **research** when discussing engineering teaching. In this case, the term scholarship should be used in the same way that Ernest Boyer did in his classic monograph "Scholarship Reconsidered: Priorities of the Professoriate [3]." In that document he describes four types of scholarship which seem to be appropriate for this discussion:

1. The scholarship of discovery,
2. The scholarship of integration,
3. The scholarship of application, and
4. The scholarship of teaching.

Considering this concept of scholarship, it appears that the "Scholarship of Engineering Education" can be represented by the diagram shown in Figure 1 [1,4]. Some faculty may want to conduct rigorous educational research studies in their courses, using hypothesis testing and statistical analyses. On the other hand, some faculty may prefer to focus on delivering scholarly lectures and interacting with students on the concepts taught. Still others may want to test new technologies in the teaching classroom, such as tablet PC's.

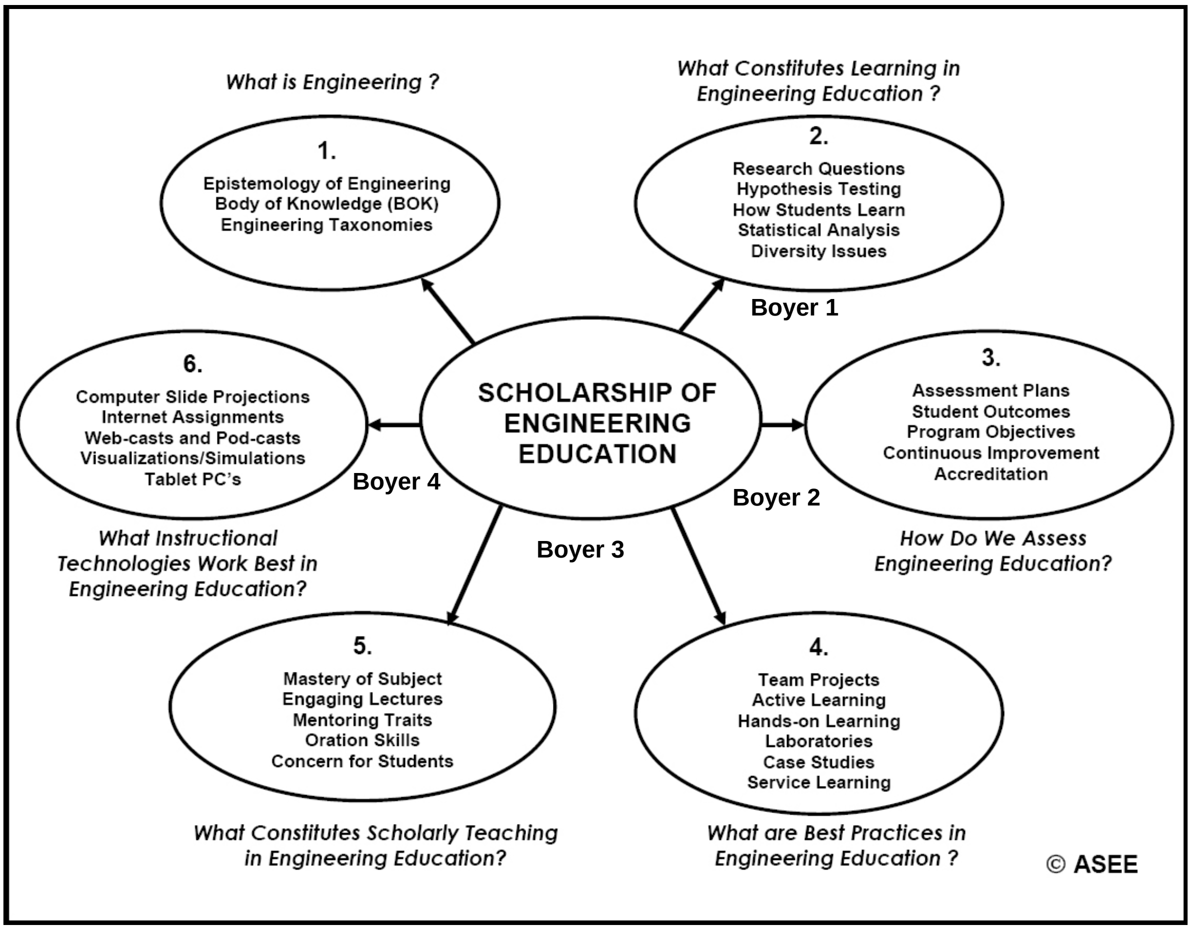

Figure 1. The Scholarship of Engineering Education [1,4].

1.2 Best Practices in Engineering Education

For some, the focus of engineering educational research is to establish and verify best practices in engineering teaching. ASEE would do well to broadly support the adoption of best practices, such as those listed in Table 1, by engineering faculty. One can only imagine that engineering teaching would make a vast improvement if every engineering faculty member in the U.S. would adopt and implement one of these best practices in the classroom.

Table 1. Some Examples of Best Practices in Engineering Education.

1.	Project-Based, Problem-Based, Challenge-Based Learning [5].
2.	Active and Interactive Learning, Hands-On Learning [6].
3.	Multi-media Videos and Computer Simulations [7].
4.	Tablet PC with Projection System [8].
5.	Socratic Dialog and Group Discussions [9].
6.	Internet and Asynchronous Learning Sites [10].
7.	Webcasts, Podcasts, Social Networking, Twitter Lectures [11].
8.	Community Projects, Service Learning [12].

Table 2. Multi-Level Tiers for Engineering Teaching Excellence

1. Excellent Engineering Teacher • Has excellent content pedagogy • Receptive to and concerned with student learning • Receives excellent student ratings
2. Scholarly Engineering Teacher • Is a (1) Excellent Engineering Teacher • Collects class data and other information to assess student learning • Uses this data to continuously improve the course
3. Scholar of Engineering Teaching • Is a (2) Scholarly Engineering Teacher • Shares learning and assessment findings with the EER community through presentations, conference proceedings, and journal publications • Receptive to feedback from EER community
4. Engineering Educational Researcher • Is a (3) Scholar of Engineering Teaching • Develops original theories and models of engineering student learning • Publishes original findings in leading engineering education journals • Is a member of the EER community

1.3 Multi-Level Tiers for Engineering Teaching Excellence

Some have proposed recognizing excellence in engineering teaching by establishing an ASEE teaching certificate program. The program would recognize teaching at different levels, for example as proposed in Table 2 [4]. Recognized teaching excellence would start with a faculty member who is recognized as excellent by students. The certificate ranking would then increase in proportion to the level of educational research conducted and published, culminating with becoming a recognized member of the engineering educational research (EER) community.

2. Methods

Challenge-based instruction was the best practice implemented by the author in the ME 354M "Biomechanics of Human Movement" course in the Fall 2004 semester [13]. This best practice was derived from considerable research and development by the NSF-funded VaNTH coalition of universities and faculties [14]. Considerable assessment was conducted during that 2004 course to determine the efficacy of this best practice. The author taught the same ME 354M course again in the Fall 2007, repeating the exact same teaching and assessment practices as in the 2004 version.

2.1 Challenge-Based Learning in Biomechanics

The challenge-based learning modules for biomechanics are presented in detail in Barr, et. al [15]. The overarching theme is to present interesting problems (challenges) to the students, and then through a guided process called the Legacy Cycle [16], to have the students learn basic biomechanics topics as needed to solve the interesting problems. Typically, the students solve the challenges in teams of 2-3 members. The biomechanics challenges presented to the students consisted of four general themes as outlined in Table 3.

Table 3. Summary of the VaNTH Biomechanics Challenges

1**.** *Iron Cross Challenge*: How much muscle strength is required to sustain the Iron Cross position?
2. *Virtual Biomechanics Lab Challenge*: How does your whole body center of gravity move when you walk? What forces do you exert on the ground when you walk? How do the leg muscles activate during one complete gait cycle?
3. *Jumping Jack Challenge*: How high can you jump? What determines jump height?
4. *Knee Challenge*: Can voluntary contraction of the quadriceps muscle group tear the anterior cruciate ligament (ACL) during an isometric knee extension exercise?

2.2 Assessment Practices

In order to assess the learning efficacy of the biomechanics modules, a number of assessment methods were applied to the course. A pre-course general biomechanics test was administered on the first class day, and the same general test was given as a post-course test on the last class day. Shorter pre-post tests, tailored to the specific modular topics, were also administered for each of the fours biomechanics topics listed in Table 3. In order to assess qualitative aspects of learning, pre-course and post-course affect surveys were also administered. Along with the affect surveys, pre-post ABET outcomes surveys were conducted. Finally, at the end of the experience, students were asked to complete a topics matrix that correlated the information needed to solve each challenge with a taxonomic list of topics typically taught in a traditional biomechanics class.

2.3 Statistical Analyses

A statistical method, based on effect size [17], was used to determine the significant difference between the pre- and post- results for all tests. The effect size (ES) statistic is calculated using the following formula:

$$ES = \frac{AVE_{Post} - AVE_{Pre}}{pooled \quad Std.Dev.} \qquad (1)$$

where AVE_{Post} is the average post score, AVE_{Pre} is the average pre score, and pooled Std. Dev. is the average of the pre- standard deviation and the post- standard deviation. Table 4 shows the relationship between effect size and the statistical confidence level (significance) that the two data sets (pre- and post-) are different.

Table 4: Statistical Significance Based on Effect Size [17].

Effect Size	*Significance Level*
0.0	50%
0.5	69%
1.0	84%
1.2	88%
1.4	92%
1.6	95%
1.8	96%
2.0	98%
2.5	99%
3.0	99.9%

3. Results

3.1 Pre-Post Course Test

A general biomechanics test was created by the instructor for the pre-course and post-course scores. The test consisted of 30 multiple-choice questions covering a wide range of class topics. The multiple-choice method was chosen to facilitate ease and consistency in grading between the pre- and post-course conditions. The results for 2004 (N=18 students) and 2007 (N=24 students) are shown in Tables 5 and 6, respectively. It can be seen that, on the average, students correctly answered about 7.5 more questions in the post-course test versus the pre-course. The resultant effect sizes for the statistical analyses were 2.46 and 2.34. This translates into confidence levels around 98-99% that the results were significantly different. Thus, a simple pre-post course test, when constructed thoughtfully, can help determine how effective the overall educational experience is for students learning. Of course, it should not surprise anyone that students learn the material after taking an engineering course, but this assessment method can help to quantitatively prove it with the ES statistic.

Table 5. 2004 Pre-Post Course Test Scores (N=18)

Pre-Course Class Average (Std. Dev.)	*Post-Course Class Average (Std. Dev.)*	*Gain (Post-Pre)*
15.17 (3.47)	22.89 (2.81)	7.72
		Effect Size = 2.46 (99% confidence)

Table 6. 2007 Pre-Post Course Test Scores (N=24)

Pre-Course Class Average (Std. Dev.)	*Post-Course Class Average (Std. Dev.)*	*Gain (Post-Pre)*
16.75 (3.47)	24.09 (2.81)	7.34
		Effect Size = 2.34 (98% confidence)

3.2 Pre-Post Modules Test

A similar pre-post test approach was used before (after) the assignment of the four VaNTH biomechanics learning modules. In this case, the various tests were tailored to specific topics addressed in the modules. All module tests where scaled to a 5-point maximum score, and class averages were determined. The results for this assessment tool are shown in Tables 7 and 8 for the 2004 and 2007 classes, respectively. It can be seen that the effect sizes ranged from a low of 0.70 (Knee, 2004) to a high of 2.75 (Jumping Jack, 2004). This yielded confidence levels from 76% to 99.5%. The results between 2004 and 2007 are similar, with the Virtual Biomechanics Lab and Jumping Jack showing the highest confidence levels in both years.

3.3 Affect Surveys

Learning is a complex process and sometimes is hard to quantify. Qualitative measures and student surveys can sometimes shed light on the underlying processes that students use to assess their own learning. In this case, affect surveys were conducted both in pre- and post-course modes. Tables 9 and 10 show the results of such an affect survey for the 2004 and 2007 offerings, respectively. The affect survey consisted of seven questions on learning factors deemed important in an educational environment. The students were asked to rank their quality of learning in these seven affect factors using a scale of 1-None, 2-Below Average, 3-Average, 4-Good, or 5-Exceptional. The seven learning factors are listed in the left column of the tables and rate such factors as knowledge and concepts acquired, interactive discussions with classmates, self-assessment, teamwork, and interpersonal skills.

Table 7. 2004 Pre-Post Tests for the Four Topical Modules (N=18)

Module Topic	*Pre-Test Ave. (Std. Dev.)*	*Post-Test Ave (Std. Dev.)*	*Gain (Post-Pre)*	*Effect Size*	*Confidence Level*
Iron Cross	3.28 (0.63)	4.11 (0.54)	0.83	1.41	92%
Virtual Biomechanics Lab	2.55 (0.46)	3.26 (0.34)	0.70	1.78	96%
Jumping Jack	2.51 (0.39)	3.57 (0.38)	1.06	2.75	99.5%
Knee	3.30 (0.99)	3.85 (0.58)	0.55	0.70	76%

Module Topic	*Pre-Test Ave. (Std. Dev.)*	*Post-Test Ave (Std. Dev.)*	*Gain (Post-Pre)*	*Effect Size*	*Confidence Level*
Iron Cross	2.95 (1.08)	3.80 (0.93)	0.85	0.81	79%
Virtual Biomechanics Lab	2.54 (0.76)	3.36 (0.69)	0.82	1.13	85%
Jumping Jack	2.67 (0.87)	3.51 (0.74)	0.84	1.04	84%
Knee	2.86 (1.25)	3.85 (1.21)	0.99	0.80	79%

Table 9. 2004 Results of Affect Survey (N=18)

Learning Factor	Pre	Post	Gain
1. I gain factual knowledge (terminology, classifications, methods, trends).	3.82	4.00	**0.18**
2. I learn conceptual principles, generalizations, and/or theories.	3.65	3.94	**0.30**
3. I get a chance to talk to other students and explain my ideas to them.	3.55	4.32	**0.76**
4. I am encouraged to frequently evaluate and assess my own work.	3.33	3.89	**0.56**
5. I learn to apply course materials to improve my own thinking, problem solving, and decision making skills	3.61	3.91	**0.31**
6. I develop specific skills, competencies, and points of view needed by professionals in the field.	3.43	3.60	**0.16**
7. I acquire interpersonal skills in working with others in the class.	3.44	4.23	**0.79**

Table 10. 2007 Results of Affect Survey (N=24)

Learning Factor	Pre	Post	Gain
1. I gain factual knowledge (terminology, classifications, methods, trends).	3.45	4.22	**0.77**
2. I learn conceptual principles, generalizations, and/or theories.	3.45	4.11	**0.66**
3. I get a chance to talk to other students and explain my ideas to them.	3.20	4.11	**0.91**
4. I am encouraged to frequently evaluate and assess my own work.	2.85	3.83	**0.98**
5. I learn to apply course materials to improve my own thinking, problem solving, and decision making skills	3.40	3.78	**0.38**
6. I develop specific skills, competencies, and points of view needed by professionals in the field.	3.10	3.78	**0.68**
7. I acquire interpersonal skills in working with others in the class.	3.25	4.06	**0.81**

It is interesting to note that all learning factors showed a positive gain in going from the pre- to post-course stage. It is even further interesting that the same three learning factors (3, 4, and 7 – indicated gray on the tables) showed the largest gains in both the 2004 and 2007 studies.

3.4 Outcomes Surveys
Student outcomes are the knowledge, skills, and abilities that students must demonstrate at the conclusion of an academic experience. For accreditation purposes, ABET requires the demonstration of outcomes a-k [18]. Table 11 shows the student outcomes used in this study.

Students were asked to rate achievement of the outcome on a scale of 1-no ability, 2-little ability 3-some ability, 4-significant ability, or 5-very significant ability. The bar charts in Figures 2 and

3 show the results of the outcomes surveys for 2004 and 2007, respectively. On the comparative bar charts, the light-colored bar is the pre-course condition, and the dark bar is the post-course condition. As can be seen in the bar charts, many of the outcomes showed some improvement from the pre- to post-course conditions. The student outcomes that contributed most to student learning in the course are shown in Tables 12 and 13 (gray cells). It can be seen that the largest gains in student outcomes for both 2004 and 2007 occurred in Outcomes 1 (science and engineering fundamentals), 2 (problem solving), 5 (computer skills), and 7 (teamwork).

Table 11. Ten Outcomes Used in the Course (ABET a-k*)
1. Knowledge of and ability to apply engineering and science fundamentals to real problems. (a*)
2. Ability to formulate and solve open-ended problems. (e*)
3. Ability to design mechanical components, systems and processes. (c*)
4. Ability to set up and conduct experiments, and to present the results in a professional manner. (b*)
5. Ability to use modern computer tools in mechanical engineering. (k*)
6. Ability to communicate in written, oral and graphical forms. (g*)
7. Ability to work in teams and apply interpersonal skills in engineering contexts. (d*)
8. Ability and desire to lay a foundation for continued learning beyond the baccalaureate degree. (i*)
9. Awareness of professional issues in engineering practice, including ethical responsibility, safety, the creative enterprise, and loyalty and commitment to the profession. (f*)
10. Awareness of contemporary issues in engineering practice, including economic, social, political and environmental issues, and global impact. (h, j*)

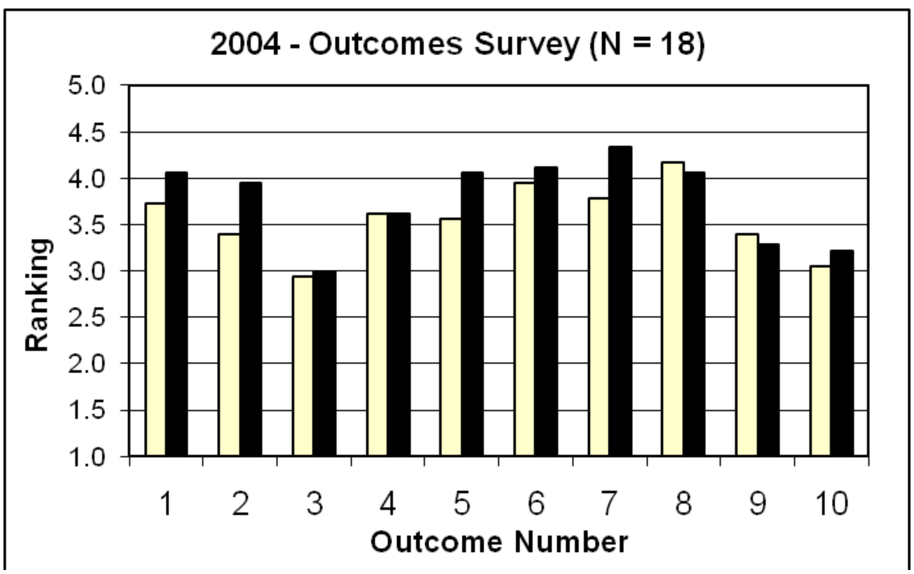

Figure 2: 2004 Student Outcomes for Pre (light) and Post (dark) Conditions.

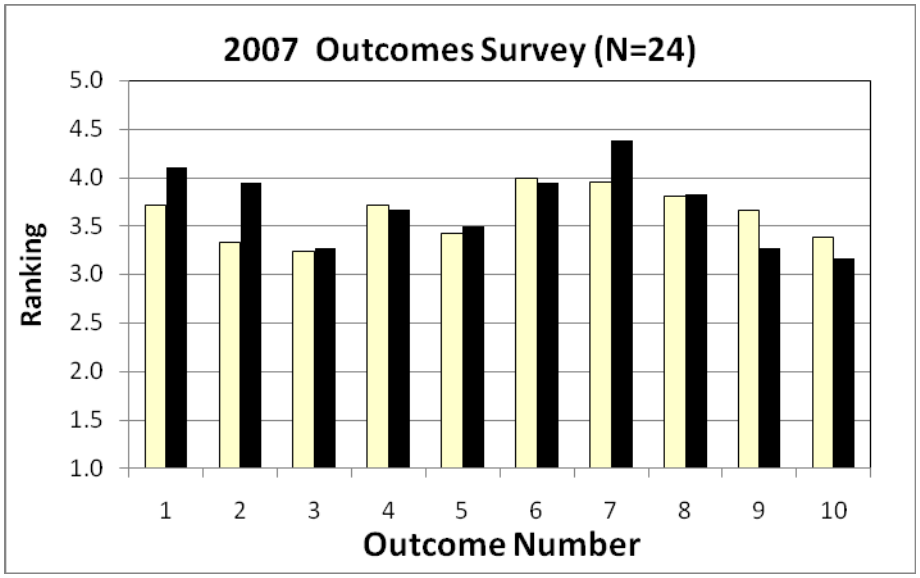

Figure 3: 2007 Student Outcomes for Pre (light) and Post (dark) Conditions.

Table 12. 2004 Student Outcomes Survey Results (N=18)

Outcome	Pre	Post	Gain
1	3.722	4.056	**0.333**
2	3.389	3.944	**0.556**
3	2.944	3.000	**0.056**
4	3.611	3.611	**0.000**
5	3.556	4.056	**0.500**
6	3.944	4.111	**0.167**
7	3.778	4.333	**0.556**
8	4.167	4.056	**-0.111**
9	3.389	3.278	**-0.111**
10	3.056	3.222	**0.167**

Table 13. 2007 Student Outcomes Survey Results (N=24)

Outcome	Pre	Post	Gain
1	3.71	4.11	**0.397**
2	3.33	3.94	**0.611**
3	3.24	3.28	**0.040**
4	3.71	3.67	**-0.048**
5	3.43	3.50	**0.071**
6	4.00	3.94	**-0.056**
7	3.95	4.39	**0.437**
8	3.81	3.83	0.024
9	3.67	3.28	-0.389
10	3.38	3.17	-0.214

3.5 Biomechanics Topics Matrix

A final survey was conducted at the end of the course. The students were asked to complete a "Biomechanics Topics" matrix. The survey form had a listing in the left-hand column of all pertinent topics that should be taught in an undergraduate biomechanics course. The students were asked to check the appropriate cells for each challenge that they felt addressed that particular topic. The results are shown in Tables 14 and 15 for 2004 and 2007, respectively. The keys below the tables indicate the density shading of each cell. Basically, if more than two-thirds of the class checked off the cell, it was shaded dark. If between one-third and two-thirds checked off the cell, it was shaded light. And if less than one-third of the class checked off the cell, it was not shaded. The total counts for each biomechanics topic are summed in the final column, and the total counts for each challenge are summed in the final row. It can be seen that almost all biomechanics topics have at least one shaded cell, and many had several. That supports the contention that the biomechanics taxonomy can be covered effectively using the VaNTH modules. It should also be noted that in 2007, the third Jumping Jack module (JJ III) was not conducted in the class due to lack of local software support.

Table 14: 2004 Results of Biomechanics Topics Matrix									
Biomechanics Topics	Iron Cross	VBL I	VBL II	VBL III	Jumping Jack I	Jumping Jump II	Jumping Jack III	Knee I	Total Counts
Skeletal System	11	8	4	4	3	3	3	16	52
Muscular System	18	10	10	16	11	14	13	15	107
Mechanical Properties of Muscle	12	1	2	8	8	10	10	10	61
Stress and Strain in Muscle	13	1	1	3	2	2	4	11	37
Classification of Human Movements	10	16	13	12	9	9	10	11	90
Joint Biomechanics	11	4	2	1	4	3	4	16	45
Dimensions, Units, Conversions	13	12	11	12	12	12	11	11	94
Anthropometrics	15	13	6	4	4	4	4	2	52
Center of Gravity Calculation	2	17	11	8	9	7	5	0	59
Moment Arm Calculation	18	3	3	2	6	7	6	10	55
Moment of Inertia Calculation	3	2	1	1	5	8	2	1	23
Radius of Gyration Calculation	1	1	0	0	1	4	1	0	8
Free Body Diagrams	17	8	11	4	8	10	8	18	84
Static Equilibrium Problem	18	2	2	2	1	2	0	14	41
Linear Kinematics	3	13	11	5	13	12	10	3	70
Angular Kinematics	4	4	4	2	6	12	8	6	46
Finite Difference Calculation	0	6	11	8	5	5	3	0	38
Dynamics of Link Segments	2	7	4	3	7	9	12	7	51
Reaction Forces	12	7	15	12	11	8	6	14	85
Torque Summation	15	1	1	1	3	11	7	15	54
Impulse-Momentum Problem	0	0	0	0	16	9	8	0	33
First-Order Systems	3	3	2	2	8	8	5	4	35
Second-Order Systems	0	0	0	1	5	10	10	1	27
Projectile Dynamics	0	0	0	0	13	14	10	0	37
Experimental Techniques	5	17	17	16	13	11	11	4	94
Experimental Equipment	4	17	17	16	13	9	10	3	89
Electro-physiology and Neural Control	0	4	4	12	2	2	4	1	29
Signal Processing of EMG	0	5	6	17	3	3	3	1	38
Computer Graphics Modeling and Simulation	2	8	10	10	5	11	13	9	68
Total Counts	212	190	179	182	206	229	201	203	

KEY (N=18)

18 – 13	√	
12 -7	√	
6 – 0	√	

Table 15: 2007 Results of Biomechanics Topics Matrix

Biomechanics Topics	Iron Cross	VBL 1	VBL 2	VBL 3	JJ 1	JJ 2	Knee	Total Counts
Skeletal System	15	8	6	7	4	3	20	63
Muscular System	23	16	16	21	15	16	20	127
Mechanical Properties of Muscle	16	10	10	12	15	19	14	96
Stress and Strain in Muscle	18	6	5	6	7	10	15	67
Classification of Human Movements	15	18	17	13	9	7	18	97
Joint Biomechanics	16	9	7	4	6	5	21	68
Dimensions, Units, Conversions	18	15	14	15	16	17	17	112
Anthropometrics	18	16	7	7	8	9	13	78
Center of Gravity Calculations	5	21	18	13	11	11	6	85
Moment Arm Calculation	23	3	2	2	8	13	15	66
Moment of Inertia Calculation	5	6	4	3	8	16	6	48
Radius of Gyration Calculation	4	3	6	4	5	10	6	38
Free Body Diagrams	22	12	13	7	10	10	21	95
Static Equilibrium Problem	22	4	2	1	1	1	19	50
Linear Kinematics	5	15	16	14	12	8	5	75
Angular Kinematics	4	5	6	6	13	19	5	58
Finite Difference Calculation	0	6	14	11	8	8	0	47
Dynamics of Link Segments	1	8	9	11	14	14	2	59
Reaction Forces	19	13	19	15	18	21	16	121
Torque Summation	18	8	10	6	13	21	13	89
Impulse-Momentum Problem	0	2	3	2	15	13	0	35
First Order Systems	7	6	8	7	12	10	7	57
Second Order Systems	0	2	3	2	10	18	0	35
Projectile Dynamics	1	2	1	2	19	21	1	47
Experimental Techniques	9	22	22	22	18	18	7	118
Experimental Equipment	6	20	21	20	16	12	6	101
Electrophysiology and Neural Control	0	7	7	16	6	9	0	45
Signal Processing of EMG	0	8	9	21	4	4	0	46
Computer Graphics Modeling and Simulation	3	12	10	10	7	18	6	66
Total Counts	293	283	285	280	308	361	279	

KEY (N=24)

24 – 17 √	(dark shading)
16 – 9 √	(grey shading)
8 – 0 √	(no shading)

4. Discussion

The results of these learning assessment studies show a number of encouraging trends. The gain from pre-test to post-test was always positive. This was true both for the whole course, as well as for each individual VaNTH module. One of the advantages of challenge-based instruction is to have students discuss the challenges together and work in teams to solve the applied problems. The results of the affect and outcomes surveys demonstrate that this contention is true.

4.1 Repeatability of Studies

One major opportunity for the author was the ability to conduct this same learning assessment study on two different occasions, in 2004 and 2007. The repeatability of the results is clearly evident. The average gains in the pre-course to post-course test were almost identical (7.72 and 7.34) and both showed an ES statistic in the 98% to 99% range. An analysis of the VaNTH pre-test and post-test results showed that the two highest ES values were in the Jumping Jack and Virtual Biomechanics modules, and that was the case for both 2004 and 2007. This result is consistent with the fact that VBL and JJ dealt with dynamics, which were harder problems, when compared to the other two challenges, which were static problems.

The three largest gains in learning factors for the affect surveys were the same for both 2004 and 2007, namely learning factors 3. “I get a chance to talk to others,” 4. “I assess my own work,” and 7. “I acquire interpersonal skills.” Likewise, the four largest gains in student outcomes for both 2004 and 2007 were the same, namely outcomes 1 (science and engineering fundamentals), 2 (problem solving), 5 (computer skills), and 7 (teamwork). Finally, even in the complex biomechanics topics matrices, similarities between 2004 and 2007 can be observed. The VaNTH module that received the most counts in the bottom row was the Jumping Jack II challenge in both 2004 and 2007. Likewise, the biomechanics topic that received the most counts in the final column is muscular system for both years.

4.2 Comment on Educational Research

The two studies presented in this paper showed consistent, repeatable, and positive results that the students learned the material using challenge-based instruction. However, this approach using the assessment tools presented, does not prove that challenge-based instruction is better than a traditional approach to teaching biomechanics. To prove that contention, a research paradigm must be implemented using hypothesis testing with both a control and a trial group. No such paradigm was used here. Thus, in reference to the earlier Table 2, the work reported in this paper would be at a scholarship tier level of 2 or perhaps 3, but certainly not a level 4.

5. Conclusions

This paper has presented some learning assessment methods for engineering courses, and has illustrated the application of these tools with data gathered in the same course taught in two different years. The results of the studies show the effectiveness in measuring student learning with these tools. The repeatability of results from 2004 and 2007 are quite demonstrable, and certainly offer a validity check for the way the two studies were conducted. One can confidently conclude that these assessment methods work for engineering courses.

Acknowledgement

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