2006-419: LEARNING STYLES OF ENGINEERING & ENGINEERING TECHNOLOGY STUDENTS – SIMILARITIES, DIFFERENCES AND IMPLICATIONS FOR EFFECTIVE PEDAGOGY

Eugene Rutz, University of Cincinnati

Eugene Rutz is Academic Director in the College of Engineering at the University of Cincinnati. Eugene's responsibilities include new program development, distance learning program development, and evaluation of instructional technologies. He has a BS in Nuclear Engineering and an MS in Mechanical Engineering and is a registered professional engineer. Eugene has worked in the nuclear power industry, as a design engineer, and as a university researcher and instructor.

Virginia Westheider, University of Cincinnati

Virginia Westheider is Academic Director in the College of Applied Science at the University of Cincinnati.

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Introduction

The academic community has long recognized that individuals have a variety of learning styles and preferences for receiving and processing information. In engineering and engineering technology education, we have seen that undergraduate education has failed to provide instruction in a manner that is engaging and relevant to large numbers of undergraduates. Implications of this failure in pedagogy are that students do not perform as well as possible and that students leave engineering to study other areas. If universities are to increase the number of well-prepared practicing engineers and technologists, especially given flat enrollments, improvements must be made in the educational process.

Beginning in 2000 with a grant from the GE Foundation, the University of Cincinnati began collecting learning style data on engineering students to seek to understand differences in student performance, particularly as it related to educational technologies[1]. This data collection was extended to engineering technology students with the implementation of a grant from the NSF's Bridges for Engineering Education program (grant # EEC-0341842). This project also sought to quantify differences in student performance and engagement with various learning technologies[2]. Kolb's Learning Styles Inventory was used as a measure of student learning styles preferences.

This paper reports on several aspects of these projects and compares our results to published studies regarding the learning styles of students. Two questions are addressed: 1) how do engineering and engineering technology students at the University of Cincinnati compare to other similar populations?; 2) are there significant differences in the learning styles of engineering students as compared with engineering technology students? Educators who understand these various preferences and who have a good sense of the distribution of learning type have a better opportunity to enable all students to learn more fully.

There are a number of interesting and important aspects of learning styles that the paper does not address. In particular, we did not examine how a student's preference might change as a result of their experiences in an engineering program or an engineering technology program. We also did not evaluate the efficacy of several learning style instruments. While the paper provides discussion on the implications of what was learned, a measure of the effectiveness of these recommendations was not a part of the scope of the study. The study does provide a snapshot of a relatively large population of students and seeks to answer specific questions about this population regarding learning styles.

Description of Learning Style Model

Personality, experience, and preference for how information is received contribute to differences in how individuals learn. These differences in learning styles challenge an educational system that assumes everyone learns equally well in a classroom lecture setting. David Kolb describes a model of understanding learning styles that focuses on two distinct processes: 1) prehension of experiences and 2) formulating meaning (transforming experiences)[3,4]. The model describes the grasping of ideas along a continuum of concrete experience to abstract conceptualization and the formulation of meaning along a continuum from reflective observation to active experimentation. Kolb's model describes an idealized learning cycle that includes all elements in the model - experiencing, reflecting, thinking and acting – in a recursive cycle as illustrated in Figure 1.

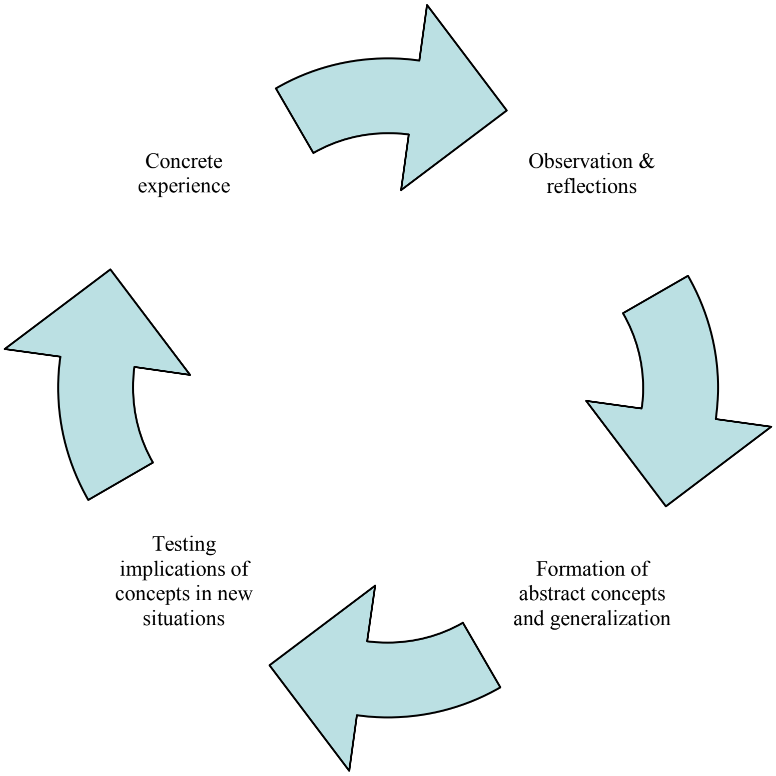

Figure 1 Idealized Learning Cycle (adapted from Kolb[4])

Kolb's method goes on to describe four different learning modes: concrete experience, reflective observation, abstract conceptualization, and active experimentation. These are illustrated in Figure 2. This theory of learning proposes four distinct learning styles which describe individual differences based on preferences for understanding and transforming experiences. While some theories of learning base individuals' preferences solely around personality traits, Kolb suggests that personality, educational specialization, professional career, current job expectations, and an individual's adaptive competencies all influence the preferred learning style[4].

Individuals display attributes of all learning elements, but Kolb's model categorizes individuals into one of four styles based on their preferences. The *convergent* learning style relies primarily on the dominant learning abilities of abstract conceptualization and active experimentation. The strength of this learning style is in problem solving, decision-making and practical application of ideas. Ideas are organized for solving problems using deductive reasoning. The *divergent* learning style relies on concrete experience and reflective observation. The greatest strength of this learning style is in being able to organize information from a variety of perspectives. *Assimilation* learning styles are identified by abstract conceptualization and reflective observation. The strength of this style is in inductive reasoning and the ability to create theoretical models. The fourth style, *accommodation*, emphasizes concrete experience and adaptive experimentation. The strength of this style is in carrying out plans and tasks, risk taking and action.

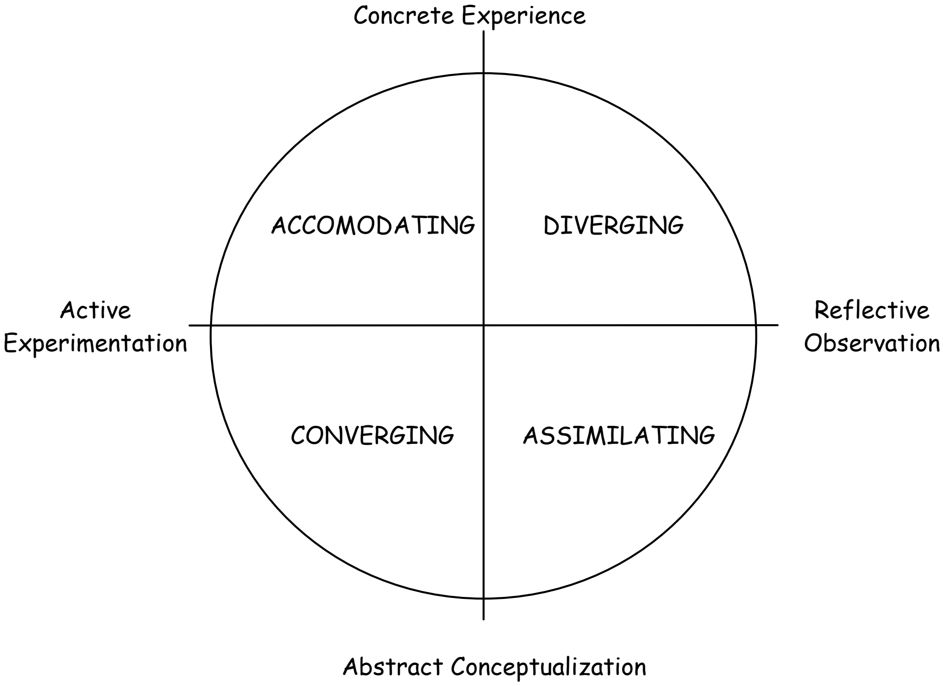

Figure 2 Kolb's Learning Styles (adapted from Kolb[3])

To determine students' primary characteristics for learning, a 12 part questionnaire is administered. Individuals select responses to the items based on a ranking of preferences. The responses indicate an individual's preferences for the two processes described earlier: prehension of experiences (the axis that connects concrete experience with abstract conceptualization in Figure 2) and formulating meaning (the axis that connects active experimentation with reflective observation in Figure 2). One of the results of completing the questionnaire is an indication of an individual's relative strength in these four processes. Another result is that each student is assigned a primary learning style as indicated by the quadrants illustrated by Figure 2.

Data Collection

The University of Cincinnati's College of Engineering received a grant from the GE Fund to evaluate the relationship between student learning styles, use of instructional technology, student performance, and student acceptance of instructional technology. The goal of the project was to determine how to use instructional technologies to optimize the learning process for students with different learning styles and personality types. The project sought to expand the body of knowledge on learning style and student performance by including the use of instructional technologies as a major variable. From 1999 through 2001, the college collected learning style information on freshmen and sophomores who participated in the courses that formed the nexus of the study[6,7].

The authors were awarded an NSF planning grant in 2004 through the Bridges for Engineering Education program. The grant enabled us to develop technology-enabled content and evaluate its effectiveness for engineering students and engineering technology students. The content was developed collaboratively among the College of Engineering, the College of Applied Science, and the College of Education, Criminal Justice and Human Services. During pilot-testing, we have evaluated the effectiveness of the educational modules and the student satisfaction with the modules. Kolb's Learning Styles Inventory was used as a measure of student learning styles preferences for second year students in both engineering and engineering technology[2]. After the completion of the grant work, the LSI continued to be used in the College of Applied Science to help freshmen engineering technology students understand their preferred style of learning and the implications this had for their education.

The results of the learning style assessments were conglomerated with additional studies performed at the University of Cincinnati in the time frame 1999 through 2005. Six hundred and two engineering students and one hundred and forty three engineering technology students participated in the data collection. Table 1 compares the preferred learning styles for engineering technology students and engineering students according to the types enumerated by Kolb.

Table 1 LSI Categories – College of Applied Science and College of Engineering

LSI Category	Engineering Technology	Engineering
Accommodators	30 (21%)	61 (10.1%)
Divergers	31 (22%)	52 (8.6%)
Assimilators	46 (32%)	232 (38.5%)
Convergers	36 (25%)	257 (42.7%)

Discussion

Using Kolb's methods, engineers (and by inference engineering students) have consistently demonstrated preference for abstract conceptualization over concrete experience while being fairly balanced between active experimentation and reflective observation. Engineers have been described both as predominantly Convergers[3] and Assimilators[4]. The results presented in Table 1 for engineering students are consistent with these studies.

The results indicate an expected greater preference in the engineering technology disciplines for concrete experience over abstract conceptualization as compared to the engineering students. Forty-three percent of engineering technology students demonstrated this preference as compared to only nineteen percent of the engineering students. We did not expect to find as "balanced" a profile in the engineering technology students as was exhibited. The authors were not able to identify other published results using Kolb's methods for engineering technology students.

Using a two-sided z test of proportions, the proportion of students in engineering technology who display a particular learning style was compared to the proportion of engineering students with the same learning style.

- The difference in proportion of engineering technology students to engineering students who demonstrated an Accommodating learning styles was significant, $z=3.56$, $p=0.0$, $\alpha=0.05$.

- The difference in proportion of engineering technology students to engineering students who demonstrated a Diverging learning styles was significant, $z=4.46$, $p=0.0$, $\alpha=0.05$.

- The difference in proportion of engineering technology students to engineering students who demonstrated an Assimilating learning styles was not significant, $z=1.41$, $p=0.156$, $\alpha=0.05$.

- The difference in proportion of engineering technology students to engineering students who demonstrated a Converging learning styles was significant, $z=3.85$, $p=0.0$, $\alpha=0.05$.

To test overall significance in the proportions, a Chi-Squared test was performed using the engineering technology sample as the observed values with the expected values derived from the proportions of engineering students displaying a particular learning style. A χ^2 value of 57.1 was calculated with 3 degrees of freedom demonstrating that the two populations are significantly different.

Results for University of Cincinnati students are compared with other published results in Table 2. The sample from Sienna College is for a mix of arts, science and business students (n=111); the sample from RIT also represents a mix of arts, science and business students (n=111); the sample from BYU is for engineering undergraduates (n unknown); the sample from Murdoch is for engineering freshmen (n=69); the sample from UNC Charlotte is for undergraduates enrolled in psychology and education courses (n=61); the sample from Kolb is a conglomeration of studies involving engineering students (n=436).

Table 2 Comparison of LSI from Various Studies

Sample	Accommodators	Divergers	Assimilators	Convergers
UC Engineering	10%	9%	38%	43%
UC Eng Technology	21%	22%	32%	25%
Sienna College[8]	30%	26%	24%	20%
RIT[8]	24%	40%	23%	14%
BYU Engineering[9]	20%	10%	40%	30%
Murdoch Engineering[10]	12%	14%	32%	42%
UNC Charlotte[11]	25%	31%	21%	23%
Kolb Engineering[4]	24%	11%	32%	33%
Kolb All Students[4]	30%	18%	29%	23%

For those studies representing engineering student populations (the shaded rows), there is a significant range for each of the learning styles with the greatest variation along the transforming experiences axis (active experimentation to reflective observation). The UC engineering student sample is certainly the most marked along the prehension axis with greater than 80% of students preferring abstract conceptualization over concrete experience while Kolb indicates the percentage is around 65% for this population. This result was not expected in that at the University of Cincinnati, cooperative education is a mandatory requirement in the engineering curriculum. With this requirement, our expectation was that students would be more inclined toward concrete experiences as compared with other engineering students. Figure 3 is a graphical representation of the engineering student populations.

The number of studies that have been identified in the literature dealing with this student population is small. Likewise the sample sizes of the published studies are limited. It is clear that the learning styles profile of this population is not well known or documented.

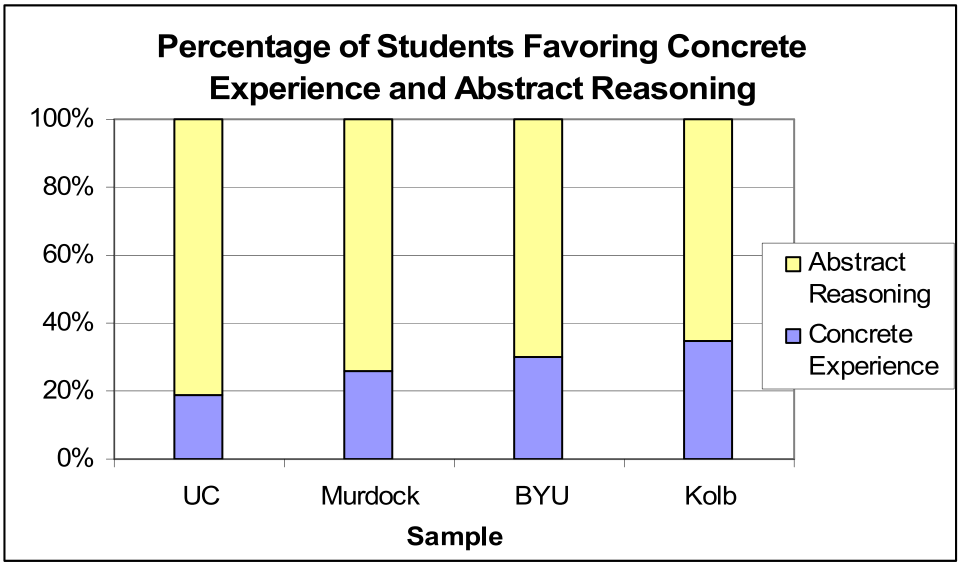

Figure 3 Engineering Students Preference for Abstract Conceptualization

Figure 4 illustrates the variation in the samples regarding the formulation of meaning from experiences. The samples are much more consistent and relatively evenly distributed along this continuum.

Using a two-sided z test of proportions, the proportion of UC students in engineering who display a particular learning style was compared to the proportion of engineering students reported by Kolb with the same learning style.

- The difference in proportion of students who demonstrated an Accommodating learning styles was significant, $z=6.07$, $p=0.0$, $\alpha=0.05$.

- The difference in proportion of students who demonstrated a Diverging learning styles was not significant, $z=1.28$, $p=0.2013$, $\alpha=0.05$.

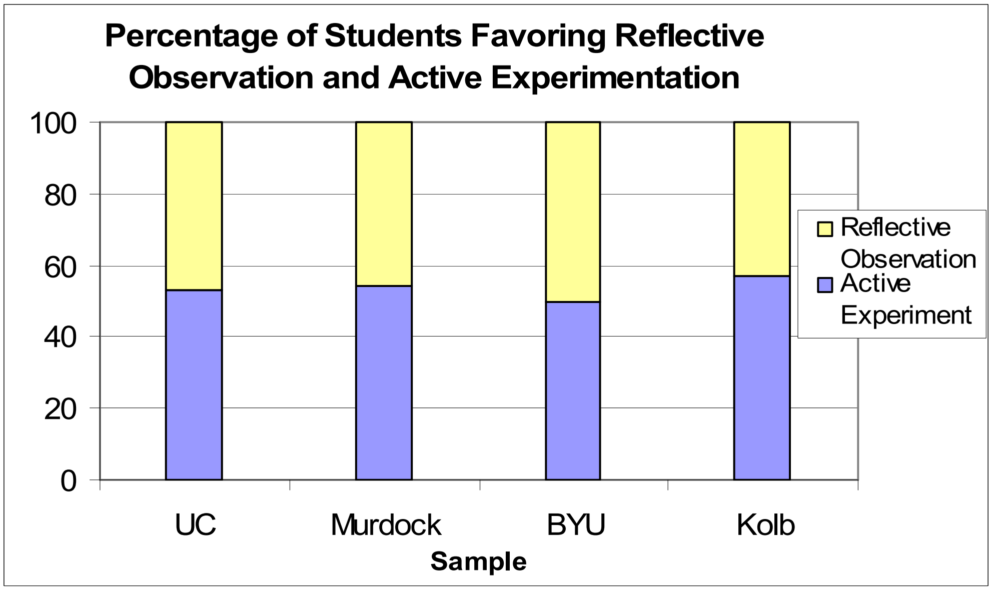

Figure 4 Engineering Students Preference for Formulating Meaning

- The difference in proportion of students who demonstrated an Assimilating learning styles was significant, $z=2.209$, $p=0.0272$, $\alpha=0.05$.

- The difference in proportion of students who demonstrated a Converging learning styles was significant, $z=3.156$, $p=0.0016$, $\alpha=0.05$.

To test overall significance in the proportions, a Chi-Squared test was performed using the UC engineering student sample as the observed values with the expected values derived from the proportions of engineering students described by Kolb as displaying a particular learning style. A χ^2 value of 76.7 was calculated with 3 degrees of freedom demonstrating that the two populations are significantly different.

The engineering technology students displayed a learning style profile closer to a general student population than did any of the engineering student studies. The profile of the engineering technology student population (observed values) was compared with the profile from Kolb of all students (n=4679) using a Chi-Squared test of overall significance. A χ^2 value of 5.8 was calculated with 3 degrees of freedom demonstrating that the two populations are not significantly different for an alpha level of 0.10.

We conclude from both qualitative and quantitative measures that the engineering student population is significantly different from the engineering technology student population regarding preferred leaning styles. We likewise conclude that the engineering student population at the University of Cincinnati demonstrates a learning styles profile that differs significantly from that described by Kolb. Finally we conclude that the learning styles profile of engineering technology students is comparable to the profile of a general student population.

Implications for Effective Pedagogy

Felder[12] examined four different learning style models (the Myers-Briggs Type Indicator, Kolb's Learning Styles Inventory, Herrmann's Brain Dominance Instrument and the Felder-Silverman instrument) and concluded that the choice of model was not of paramount importance. Rather, any instructional approach that taught around a complete cycle of learning could result in improved pedagogy. Coffield et al[13] examined thirteen models of learning styles and report significant differences in validity and utility. Coffield et al go on to comment that there exist dangers in recommending detailed strategies to practitioners since the theories and instruments that implement the theories are not equally useful. Similarly, there is no consensus regarding the implications for effective practice.

Our own review of the literature leads us to conclude that many of the claims regarding efficacy of teaching to learning styles are over stated. However all one needs to do is spend time in the classroom and in honest conversation with students to conclude that individuals differ (at times drastically) in how they learn. The authors agree that pedagogy can improve through understanding of these differences and properly addressing the variety of styles exhibited by students. Felder and Silverman[5] and Harb et al[9] provide excellent discussion on using a variety of instructional methods to engage all learners. Rather than repeat what is presented well by those authors, we offer the following as additional benefits for the use of learning style assessment in higher education.

Use of learning style assessment provides students a taxonomy of learning and a means of articulating the ideas associated with learning. For most students (and many educators) this is a new experience. With this language they are better able to discuss their own learning preferences, how people learn and fail to learn, and how educators might improve this process.

By going through a learning style assessment, students are more self aware of their own characteristics and the characteristics of others. This self knowledge can provide a basis for understanding why particular learning activities are well received and why others are not. It can also help individuals make changes to activities to enhance their potential for learning.

When students and instructors can both articulate characteristics of learning styles, it enables a meaningful dialogue to occur. This is perhaps the best outcome in that it holds the promise for the most significant change in behavior. When an educational climate of dialogue around approaches to learning, activities, and assessments takes place, pedagogy can improve.

Given that we found significant differences in the learning style profiles of engineering and engineering technology students, there are a number of implications for educators. Notwithstanding the limitations of learning style theories, there are a number of practical observations that can be made using the taxonomy of Kolb's model.

The first implication is one of recognition; if educators treat the two populations identically, the efficacy of the learning activities is likely to be more effective for one group than the other. This has practical implications for institutions at which both student populations are in the same college. For example, learning activities that were designed to appeal to engineering students by emphasizing theory would be un-engaging and less effective for many of the engineering technology students.

The second observation is also one of simple recognition; the number of Divergers and Accommodators among the engineering students is small. The implication is that these individuals may find themselves on the "short end" of activities designed to appeal to the majority of their peers. Likewise, they may find that their approach to learning is underappreciated by both peers and faculty. The further implication is that such students will have a more difficult time being successful in this field of study and are more likely to leave engineering for other fields. We do not have data to substantiate this observation; it is only as stated, an observation.

Given the more balanced distribution of learning styles among engineering technology students, the need to provide a balance of instructional approaches is greater than for engineering students. Faculty who teach engineering technology students have the opportunity to help significant numbers of students by providing instructional activities that appeal to all learning styles. On the "other side of the coin", it is essential to use activities that teach around a learning cycle in order to keep a greater number of engineering students engaged in the discipline. While a traditional approach that emphasizes theory would seem to appeal to a majority of (UC) engineering students, all students would be well served by developing skills across the learning cycle.

Because of the more balanced profile of the engineering technology students, this population is expected to have a greater awareness of and appreciation for diversity in approaches to learning and problem solving. One implication is that a team of engineering technology students working on a project is more likely than a team of engineering students to identify multiple approaches to a task or problem. Given the profile of the engineering students, they are more likely to be like-minded in problem solving and learning. There is a growing body of literature (see for example Leonard and Strauss[14]) that suggests organizations benefit when individuals are comfortable and competent at working with diversity in problem solving. Engineering students may need to be taught this skill more so than engineering technology students.

At the University of Cincinnati, current activities are focusing on education faculty on the concepts associated with learning styles and the variations in preferences among the students. Faculty development workshops have been offered on learning styles and pedagogy and effective use of technology to enhance learning. Faculty are also encouraged to take advantage of the Center for the Enhancement of Teaching and Learning, a university resource focused on the development of effective pedagogies.

Conclusion

Student groups that may have some similar characteristics nonetheless can display significant differences in other aspects that affect learning. Educators who are aware of these differences and who can articulate these characteristics have a better opportunity to develop instruction that is effective for a variety of learners. Students who are introduced to learning style models and Kolb's Learning Style Inventory (LSI) can become stronger in understanding their strengths and preferences and in using the cycle of learning, all learning styles, which will enable them to become more successful learners.

From our comparisons of various student populations, it is clear that a particular institution should not expect students to display learning profiles that have been attributed to a similar population. There is not yet sufficient published literature to adequately describe the attributes of students from which one can make conclusions regarding learning styles.

Bibliography

[1] Rutz, E., R. Eckart, J. E. Wade, C. Maltbie, C. Rafter, V. Elkins, "Student Performance and Acceptance of Instructional Technology: Comparing Technology-Enhanced and Traditional Instruction for a Course in Statics," *Journal of Engineering Education*, Vol. 92, No. 2, pp 133-140, April 2003.

[2] Rutz, E., V. Elkins, J. Pittman, M. Rabiee, and R. Miller, "Technology-Enabled Content in Engineering Science Curriculum," *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition,* Portland, OR, June 2005.

[3] Kolb, D.A., *Experiential Learning. Experience as the Source of Learning and Development*. Prentice-Hall. Englewood Cliffs, NJ. 1984

[4] Kolb, A. and D. A. Kolb, "The Kolb Learning Style Inventory – Version 3.1 2005 Technical Specifications". HayGroup (available at www.hayresourcesdirect.haygroup.com/). 2005.

[5] Felder, R.M, and L.K. Silverman, "Learning and Teaching Styles in Engineering Education." *Engineering Education*. 78(7) pp. 674-681. 1988

[6] Rutz, E. V. Elkins, C. Rafter, A. Houshmand, R. Eckart, "Evaluation of Learning Styles and Instructional Technologies", *Proceedings of the 2000 American Society for Engineering Education Annual Conference & Exposition*, St. Louis, MO, June 18-21, 2000.

[7] Eckart, R., V. Elkins, T. Heidotting, C. Rafter, E. Rutz and J. Wade "Utilizing New Instructional Technologies to Optimize the Learning Process", *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, Albuquerque, NM, June 24-27, 2001.

[8] Reading-Brown, M.S. and R.R. Hayden. "Learning Styles – Liberal Arts and Technical Training: What's the Difference?" *Psychological Reports*. 64 pp. 507-518. 1989.

[9] Harb, J., P. Hurt, and K. Williamson, *Teaching Through the Cycle – Application of Learning Style Theory to Engineering Education at Brigham Young University*. Provo, Utah. BYU Press. 1995

[10] Fowler, L. D. McGill, J. Armarego, and M. Allen, "Quantitative learning conversations: Constructivism and its application to learning in an engineering environment," *Proceedings of the Higher Education Research and Development Society of Australasia annual conference*, HERDSA 2002, Perth, Australia, pgs 254 – 262 (www.ecu.edu.au/conferences/herdsa/main/papers/ref/pdf/Fowler.pdf) 2002.

[11] Buch, K. and C. Sena, "Accomodating Diverse Learning Styles in the Design and Delivery of On-Line Learning Experiences," *Int. J. Engng Ed*. Vol. 17, No. 1, pp. 93-98. 2001

[12] Felder, R.M. "Matters of style." *American Society of Engineering Education: Prism*, 6(4), 18–23. 1996.

[13] Coffield, F, D. Moseley, E. Hall, and K. Ecclestone, "Should we be using learning styles? What research has to say to practice," Learning and Skills Research Centre. www.LSRC.ac.uk. London, UK. 2004.

[14] Leonard, D. and S. Strauss, "Putting Your Company's Whole Brain to Work," *Harvard Business Review*. Reprint Number 97407. July 1, 1997.