Hands-on Experiences to Enhance Learning of Design: Effectiveness in a Redesign Context When Correlated with MBTI and VARK Types

Dr. Daniel Jensen, Capt. Martin Bowe

Dept. of Engineering Mechanics, United States Air Force Academy

1. ABSTRACT

Based on data from a previous study, we have made significant changes to our sophomore Introduction to Design course at the United States Air Force Academy. The two most important changes have been the division of the course into separate redesign and original design components and the incorporation of extensive hands-on content into the course. The first half of the semester is spent working on a reverse engineering / redesign project. During this half of the semester, 75% of the lectures now have a significant hands-on component. The primary purpose of this paper is to report on the effectiveness of this hands-on content. In addition, we will provide an overview of the division of the course into redesign and original design sections. The primary assessment tool being used is a survey which students fill out after each lecture. Each student survey took approximately a minute to complete and was designed to differentiate between four things: 1) student's interest in that lecture's subject matter, 2) that day's learning experience, 3) their ability to apply material covered that day and 4) their interest in exploring that lecture's material further. The results from the surveys are correlated with the students' Myers Briggs (MBTI) type as well as the type of "learner" they are, as measured by the VARK learning styles instrument. Results indicate that the hands-on content is very helpful for the MBTI S-type students (hands-on content ranked in 62nd percentile overall), while it is not as helpful for the MBTI N-type students (hands-on content ranked in 52nd percentile overall). VARK learning style "K" type students responded favorably to the hands-on content (55th percentile) while "non-K" types responded negatively (43rd percentile) to the hands-on content.

2. INTRODUCTION

Beginning in the Fall semester of 1997 and continuing on to the Fall of 1998, a restructuring of the first design course at the United States Air Force Academy has been accomplished. Historically, this first design course has been based on learning a design process followed by one original design project at the end of the course. The original design project was often the ASME design competition.

Beginning in the Fall semester of 1997 and continuing to the present, the restructured course has included an introduction to the design process using Ullman as a guide [Ullman], but has also incorporated a redesign/reverse engineering process using the work of Otto et .al. [Otto1,2]. Specifically, the first half of the course taught design tools by means of redesigning a simple child's toy, thus providing a "hand's-on" aspect to which the tools could be immediately applied. Upon completion of the redesign project, an original design was embarked upon, again using an ASME competition. The original design was then the student's second time going through the design process. The restructured course therefore provides an avenue to learn and apply the subject matter intuitively with sensory inputs from a hands-on article directly in front of them rather than learning a theory to be applied much later in the course.

During the Fall'97 and Spring '98 semesters, a study was done to evaluate the effectiveness of the restructuring. Students were asked to rate each lecture on a scale of 1-10. These ratings were correlated with certain aspects of each lecture (amount of hands-on content, content abstractness, amount content was "step-by-step" and perceived applicability of content). These results were combined with the students' Myres Briggs Type Indicator (MBTI) type to provide data indicating how different MBTI types respond to certain lecture content. Specifically, we determined that MBTI S-types responded well to hands-on content while N-types responded less favorably to this content. This work was reported at last year's ASEE conference [Jensen3, Otto2].

The present work builds on these previous results in three ways: 1) additional hands-on content added to the course is evaluated, 2) while the previous survey asked only for a general "lecture rating", the present survey instrument has been refined to provide data on learning, interest level, application ability and curiosity for future study. 3) In addition to the MBTI tool, a new instrument called the VARK learning style inventory [Fleming] is used.

3. OVERVIEW OF THE COURSE RESTUCTURING

3.1 Restructured Course Content

As previously mentioned, before the Fall semester of 1997, this course followed the mechanical design process as described by Ullman. While the general course material and design competition usually received high ratings, students evaluated the content on design methods poorly. Typical responses stated that the material was taught at a very high level and in a compartmentalized fashion. There did not appear to be clear relevance and hands-on experiences to deal with abstract topics, such as functional modeling and quality function deployment.

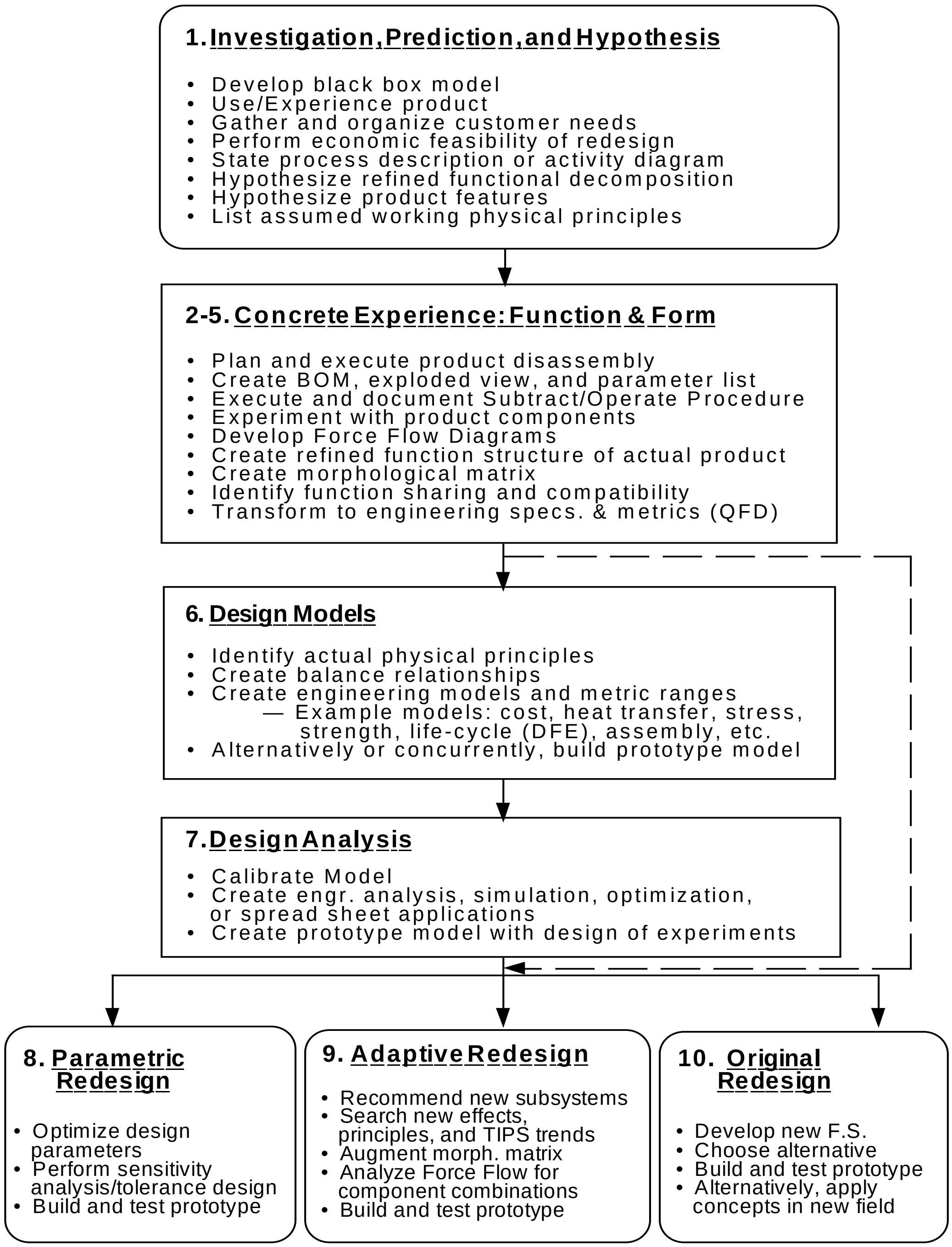
To address these issues, the restructuring involved adding a significant redesign component to the course and adding significantly more hands-on content than was previously included. Approximately 75% of the lectures in the first half of the present course contain significant hands-on content. Reverse engineering of household products or toys provide the foundation for redesign and the new hands-on emphasis [Otto1,2]. For the first half of the course, students apply the course material directly to products chosen for redesign (such as mechanical and electro-mechanical toys, power tools, kitchen appliances, etc.). They also learned novel techniques for disassembling and evolving product architectures [Lefever, Otto1,2]. By so doing, the students often had a physical object in their hands to test their understanding of the course materials. Hands-on products, in this sense, provided a forum to dissect, to measure, to experiment, to visualize, and to evolve their ideas into wonderful new creations.

After learning and applying design techniques to the reverse engineering projects, the second half of the course focused on an original-design problem. Design competitions were again the focus, but the students carried with them a grounding of the techniques from reverse engineering / redesign. They could now apply techniques, such as specification generation, customer needs analysis, and functional analysis, to a more general and abstract problem. In so doing, they could build on their concrete experience with an actual product, without having to simultaneously learn the mechanics of the techniques.

As stated above, the restructuring efforts focused both on incorporation of hands-on content and implementing reverse engineering / redesign projects during the first half of the course. These efforts centered around a new reverse-engineering and redesign methodology, depicted in Figure 1 and detailed in [Otto, Lefever]. Three phases compose the overall structure of the methodology: reverse-engineering, modeling and analysis, and redesign. The first stage of reverse-engineering begins with investigation, prediction, and hypothesis of a product being redesigned. Through this approach, the product is treated, figuratively and literally, as a black box to avoid bias and psychological inertia. Product disassembly and experimentation completes the reverse engineering phase, wherein the product under study is dissected to understand its function and form. Design modeling and analysis follows reverse engineering. The intent in this phase is to fully understand the physical principles and design parameters for the product. Redesign completes the methodology with a choice of three avenues for product improvement: parametric, adaptive, and original.

The execution of this process in the present course begins by giving the students a product to reverse engineer and redesign. The students are initially asked to predict how they think the product should work and gather customer requirements for later use in a QFD matrix (House-of-Quality). They then conceptualize both black box and more refined models of the predicted product's functionality and possible physical solutions (without taking the product apart). Only after this predictive phase is completed do they actually disassemble the product. They document the steps of disassembly in a disassembly plan (in order to aid in reassembling the product) and also develop a bill of materials which lists all of the parts contained within the product. An exploded view and subtract-and-operate procedure are required to make the students consider assemblability issues and to truly understand how their product fits together. Actual product function is documented and compared to the prediction. A morphological matrix is constructed using the parts and their corresponding functions, and function sharing throughout the device is investigated using force flow analysis and subtract-and-operate procedures. Once the students fully understand the physical nature of their product and its functionality, they are asked to develop complete QFD matrices for the product, including benchmarking, technical difficulty, etc. They are then expected to use the QFD results, and other data collected, to propose design changes that should be made in the product.

FIGURE 1: REVERSE ENGINEERING AND REDESIGN METHODOLOGY.



The remainder of the project is spent mathematically modeling or experimentally testing some aspect of the design, and creating an evolved product. Whether that evolved product represents only parametric changes from the original design or includes entirely new subsystems is left to the discretion of the students. This reverse engineering experience currently concludes approximately half way through the semester.

3.2 Hands-on Content in the Restructured Course

Hands-on content is incorporated into the redesign part of the course in two ways. First, the redesign project itself provides for hands-on opportunities. The last two semesters students redesigned Nerf-type dart guns. They were asked to bring their guns to class every lecture where the guns were often used as illustrations of the design method being discussed. The second manner in which hands-on content was incorporated was simply distributing a device, other than their gun, for use in discussing that day's lecture content. Examples of this included using "Quick-Grip$_{TM}$" clamps to illustrate force flow and subtract-&-operate procedures, using mechanical pencils to exemplify functional modeling and using Skil$_{TM}$ power screw drivers to stimulated discussion of overall design process and customer needs analysis.

3.3 STRUCTURE OF THE NEW SURVEY

As previously mentioned, the original survey used for the previous study asked only for MBTI type and overall lecture rating. In order to gain additional insight into the effectiveness of the hands-on content, a refined survey was developed and used for the present study. The refined survey requests information about the students' perception of interest, learning, applicability and motivation for future exploration (see Fig 2). In addition, both the MBTI and VARK types are recorded. This survey was given after each lecture in the redesign section of the course (17 lectures) and took about a minute for students to complete.

FIGURE 2 – ONE MINUTE SURVEY FORM

1 MINUTE SURVEY ME 290 - FALL 1998
Lesson #: _____
MBTI Type: _______ VARK Type: _______
Please rate the following statements on a scale from 1 to 10 (1 - very untrue; 10 - very true):
___ 1. Today's class kept me interested.
___ 2. Today's class was a good learning experience.
___ 3. This class prepared me well to apply today's concepts to problems.
___ 4. This class motivated me to further explore today's concepts.

4. USING MBTI AND VARK DATA TO IMPROVE THE COURSE

4.1 Introduction

The last few years have seen a dramatic increase in the development and implementation of learning-style techniques as they relate to engineering education [Felder1,2,3, Wankat, Solomon, Eder, Dunn, Jensen1-5]. Much of the focus has been on teaching "across the spectrum" [Felder1]; meaning that teaching formats must be designed to span the spectrum of the different manners in which students learn. A variety of techniques have been developed to categorize learning styles including: Myers Briggs Type Indicator (MBTI) [Jung, Keirsey, McCaulley1] and, more recently, the VARK (Visual, Auditory, Read/Write, Kinesthetic) tool [Fleming]. Work in the MBTI arena has included a massive study which provided percentages of different MBTI types within specific engineering disciplines [McCaulley2]. Application of the MBTI test's results has included efforts to improve creativity [Ramirez], create more effective design teams [Wilde, Brickell], aid students in their use of self-paced material [Smith] and, in general, to tailor the learning environment to meet students' differing preferences [McCaulley3, Lawrence, Jensen4, Rosati, Lunsdaime].

4.2 MBTI Background

Significant work has been done in the development of hands-on content, with the goal being overall learning enhancement [Otto2, Carlson, Kresta, Aglan, Catalano]. Some of the literature indicates that the combination of multimedia and hands-on creates a positive effect on learning [Cooper, Regan, Behr, Sheppard]. Other studies indicate that the effectiveness of the hands-on material depends on the type of content the student is attempting to master. In cases where the material is abstract, the addition of hands-on experience seems to provide an increase in learning potential. In the case of learning of more rudimentary material, such as the simple retention of facts, the supplementary hands-on material does not appear to provide significant enhancement [Laurillard, Flori]. Also, the hands-on content appears to be received differently by students with different MBTI types [Jensen4].

The present work builds on what is known from MBTI type preferences and student learning in order to guide continuing improvements in the restructured sophomore level design course at the USAF Academy. The MBTI type includes four categories of preference [Myers, Jung, Kersey, Lawrence]. The first category describes whether a person interacts with their environment, especially with people, in an initiating (extroverted) or more passive (introverted) role. Extroverts tend to gain energy from their surroundings while introverts usually gain energy by processing information internally. The second category gives information on how a person processes information. Those who prefer to use their five senses to process the information (sensors) are contrasted with those who view the intake of information in light of either its place in an overarching theory or its future use (intuitors). This sensor vs. intuitor category is seen by most researchers to be the most important of the four categories in terms of implications for education [Myers, Lawrence].

The third category for MBTI preference attempts to describe the manner in which a person evaluates information. Those who tend to use a logical "cause and effect" strategy (thinkers) are contrasted with those who use a hierarchy based on values or on the manner in which an idea is communicated (feelers). The final MBTI type category indicates how a person makes decisions or comes to conclusions. Those who tend to want to be sure that all of the data has been thoroughly considered (perceivers) are contrasted with those who summarize the situation as it presently stands and make decisions quickly (judgers). The four letter combination of these indicators (“E” vs. “I” for extrovert and introvert; “S” vs. “N” for sensor and intuitor; “T” vs. “F” for thinker and feeler; “J” vs. “P” for judger and perceiver) constitute a person’s MBTI “type”. Table 1, which is adapted from Manual: the Myers-Briggs Type Indicator [Myers, McCaully 1976], gives a brief overview of the four MBTI categories.

TABLE 1 -- OVERVIEW OF THE MBTI CATAGORIES

Manner in Which a Person Interacts With Others			
E	Focuses outwardly on others. Gains energy from others.	Focuses inwardly. Gains energy from ideas and concepts.	I
EXTROVERSION		INTROVERSION	
Manner in Which a Person Processes Information			
S	Focus is on the five senses and experience.	Focus is on possibilities, future use, big picture.	N
SENSING		INTUITION	
Manner in Which a Person Evaluates Information			
T	Focuses on objective facts and causes & effect.	Focuses on subjective meaning and values.	F
THINKING		FEELING	
Manner in Which a Person Comes to Conclusions			
J	Focus is on timely, planned conclusions and decisions.	Focus is on adaptive process of decision making.	P
JUDGEMENT		PERCEPTION	

4.3 VARK Background

The present work also builds on student learning preferences, as obtained from an instrument called the VARK Catalyst. Rather than being a diagnostic tool for determining a student’s learning preference, the VARK test serves as a catalyst for reflection by the student [Bonwell]. The student takes a simple 13-question test that is aimed at discovering how a student prefers to receive and process information.

After taking the test, the student will receive a “preference score” for each of four areas listed below [Bonwell]. The first area is Visual (V). This indicates how much the student prefers to receive information from depictions “of information in charts, graphs, flow charts, and all the symbolic arrows, circles, hierarchies, and other devices that instructors use to represent what could have been presented in words" . The second area is Aural (A). This indicates the student's preference for hearing information; i.e. the student learns best from a lecture, tutorial or talking with other students. The third area is Read/Write (R). This shows a student's preference for information displayed as words. This is perhaps the most common instructional method used in Western education . The fourth area is Kinesthetic (K). In short, this indicates a student's preference for "learning by doing." By definition, this refers to a student's "perceptual preference related to the use of experience and practice (simulated or real)" .

The scoring of the test also allows for the student to show mild, moderate, or strong learning preferences for each of the four areas. To reiterate—this test seeks only to illustrate to the students their *preferences* on how they like to learn, it is not a diagnostic tool to tell them how they learn best.

4.4 MBTI & VARK Correlation Data

In the present study, the MBTI and VARK data for students were obtained along with the student's rating for each individual lecture in the course. As previously mentioned, the goal of the study is to direct future refinement of the course to enhance student learning and to provide a framework for others to enhance their courses by employing a similar method. To this end, a four step process was used.

Step 1: Obtain Averaged Values for Each of 17 Lectures for S-type, N-type, K-type and Non-K-type Students for Each of the 4 survey Questions

Students rated each of the 17 lectures shown in Figures 3-10 on a 0-10 scale for each of the 4 questions on the 1 minute survey. The lecture ratings from students having MBTI S-type (sensor) were separated from those students who were N-type (intuitors), while those who had VARK K-type were separated from those who had Non-K-type. The individual S-type, N-type, K-type and Non-K-type student's rating were averaged for each lecture. These are the individual data points on the Figures 3-10. In the calculations below, these averaged lecture ratings are denoted $\overline{X^{Q}_{S_i}}$, $\overline{X^{Q}_{N_i}}$ $\overline{X^{Q}_{K_i}}$ and $\overline{X^{Q}_{Non-K_i}}$ for i =1,2,…17 and Q = 1,2,3,4 where the first subscript indicates the MBTI or VARK type and the sub-subscript indicates the lecture number and the superscript indicates the question number from the 1 minute survey.

Step 2: Obtain Overall Averaged Lecture Ratings and Standard Deviations for S-type, N-type, K-type and Non-K-type Students for Each of the 4 One Minute Survey Questions

For each of the four questions on the one minute survey, a mean and standard deviation was calculated for the S-types' N-types', K-types' and Non-K-types' ratings across the 17 lectures. The mean and the standard deviations for the four different types are labeled

$\overline{X}_S^{Q=1-4}$, $\overline{X}_N^{Q=1-4}$, $\overline{X}_K^{Q=1-4}$, $\overline{X}_{Non-K}^{Q=1-4}$ and $\sigma_S^{Q=1-4}$, $\sigma_N^{Q=1-4}$, $\sigma_K^{Q=1-4}$, $\sigma_{Non-K}^{Q=1-4}$ for the 4 questions for S-types, N-types, K-types, and Non-K-types respectively. Table 2 summarizes these calculations.

TABLE 2
Means and Standard Deviations for S-type, N-type, K-type & Non-K-type

TYPE	$\overline{X}^{Q=1}$	$\sigma^{Q=1}$	$\overline{X}^{Q=2}$	$\sigma^{Q=2}$	$\overline{X}^{Q=3}$	$\sigma^{Q=3}$	$\overline{X}^{Q=4}$	$\sigma^{Q=4}$
S	8.33	2.47	6.91	2.01	6.67	1.75	7.12	1.59
N	7.91	1.22	7.89	0.78	7.64	0.65	7.58	1.12
K	7.66	1.42	7.61	1.07	7.47	0.71	7.41	1.33
Non-K	8.11	1.12	7.97	0.88	7.53	0.95	7.55	1.05

Step 3: Obtain Measure of Four Content Areas For Each Lecture
The two professors who were involved in teaching this course individually evaluated each lecture indicating the amount of hands-on content that lecture had. The results from the two professors were combined, providing a somewhat averaged set of values for the amount of hands-on in each lecture. Figures 3-10 show that of the 17 total lectures, two lectures were determined to have hands-on content weight =1, two lectures were determined to have hands-on content of weight = 2 and four lectures were given a hands-on content weight =3. Note that a lecture determined by the professors to have a hands-on content weight of 3 indicates that the each student was physically interacting with their own product while that day's content was presented. A weight of 2 was used if students used a hands-on device for most, but not all of the lecture and a weight of 1 indicates that students were involved in a hands-on demo during class. The hands-on weights for each lecture are labeled HO_{WT_i} , i =1,2,…17 where the superscript "i" indicates the lecture number.

Step 4: Obtain the Percentile Rating for Each Content Area as Rated by S-types and N-types
In order to determine an S-type, N-type, K-type and Non-K-type percentile rating for each of the four questions from the 1 minute survey, the average number of standard deviations away from the mean for each content area is first computed. The computation for the first question from the 1 minute survey for S-type takes the following form:

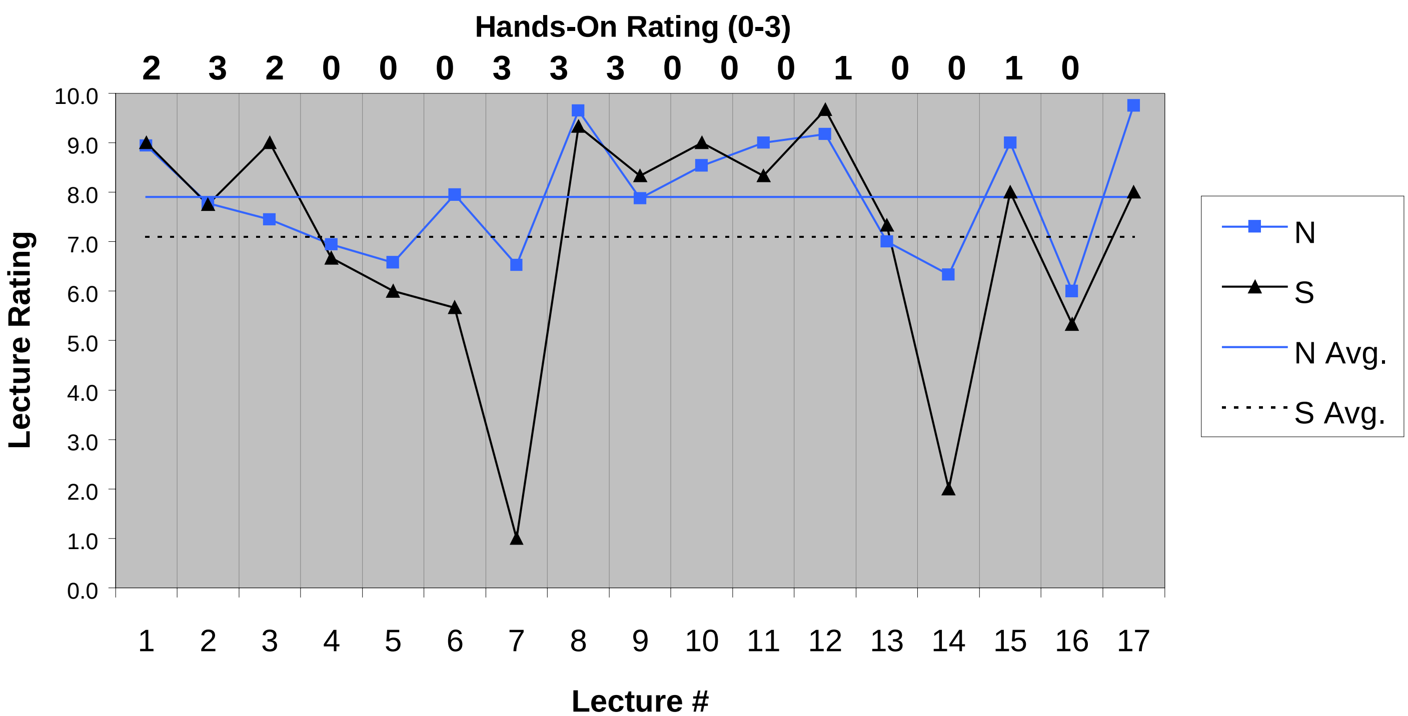
$$No.\ Std.\ Dev.\ off\ \ Mean = \frac{\left[\dfrac{\sum_{i=1}^{17}\left\{HO_{Wt_i} * X_{S_i}^{Q=1}\right\}}{\sum_{i=1}^{17} HO_{Wt_i}}\right] - \overline{X}_S^{Q=1}}{\sigma_S^{Q=1}} \quad \text{(eq. 1)}$$

Calculations for the other three questions and for the N-types, K-types and Non-K-types proceed similarly. Using results from (eq. 1) in the probability distribution function for normal, Gaussian data, a percentile rating for each of the content areas can be found for the four different types studied for each question off the 1 minute survey. The results are summarized in Table 3 where the number of standard deviations off from the mean is given with the associated percentile in parenthesis.

TABLE 3
NUMBER OF STD. DEV. OFF MEAN (PERCENTILE)
FOR QUESTION NUMBER AND TYPE

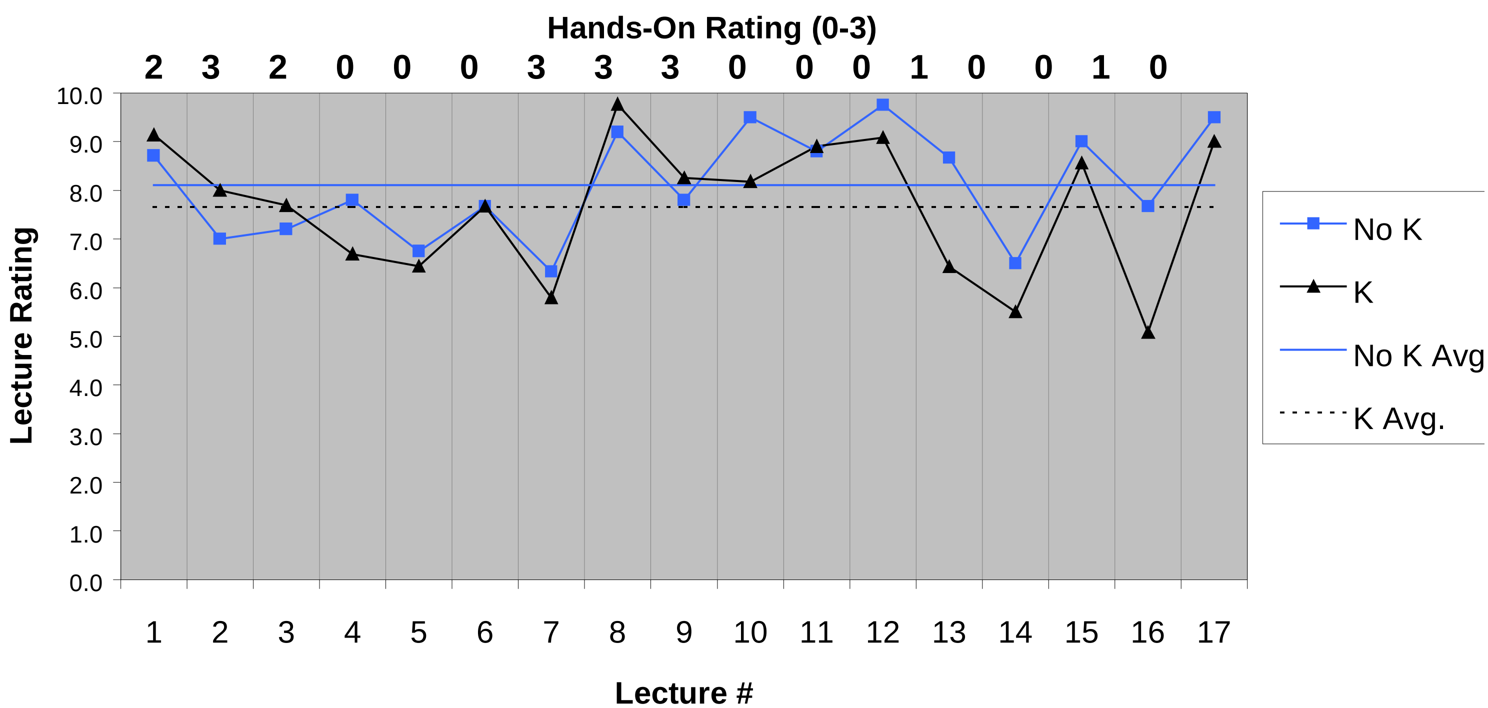
1 min. Survey Question	**S-TYPE**	**N-TYPE**	**K-TYPE**	**NON-K-TYPE**
Q1: Lecture was interesting?	0.50 (70)	-0.05 (48)	0.11 (58)	-0.34 (37)
Q2: Lecture helped me learn?	0.20 (58)	-0.01 (50)	0.06 (52)	-0.45 (33)
Q3: Lecture helped me to apply material?	0.22 (59)	0.20 (58)	0.12 (55)	0.26 (56)
Q4: Lecture motivated me to explore subject further?	0.23 (59)	0.07 (53)	0.13 (55)	0.14 (45)

Fig 3. Hands-On Content: Did It Keep You Interested?



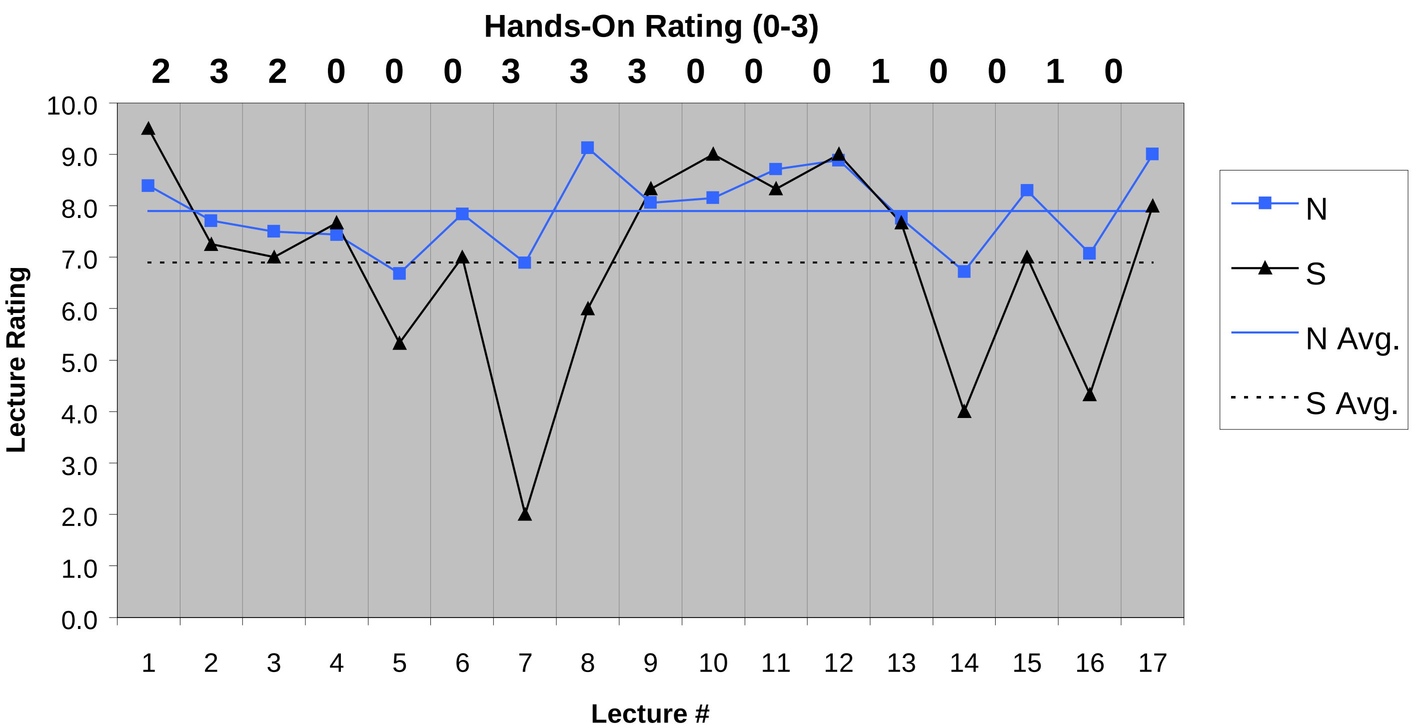
Note: N students rated hands-on lectures an average of 0.05 standard deviations (2%) **lower** than their "average lesson" while S students rated them 0.5 standard deviations (20%) **higher**.

Fig 4. Hands-On Content: Did It Keep You Interested?



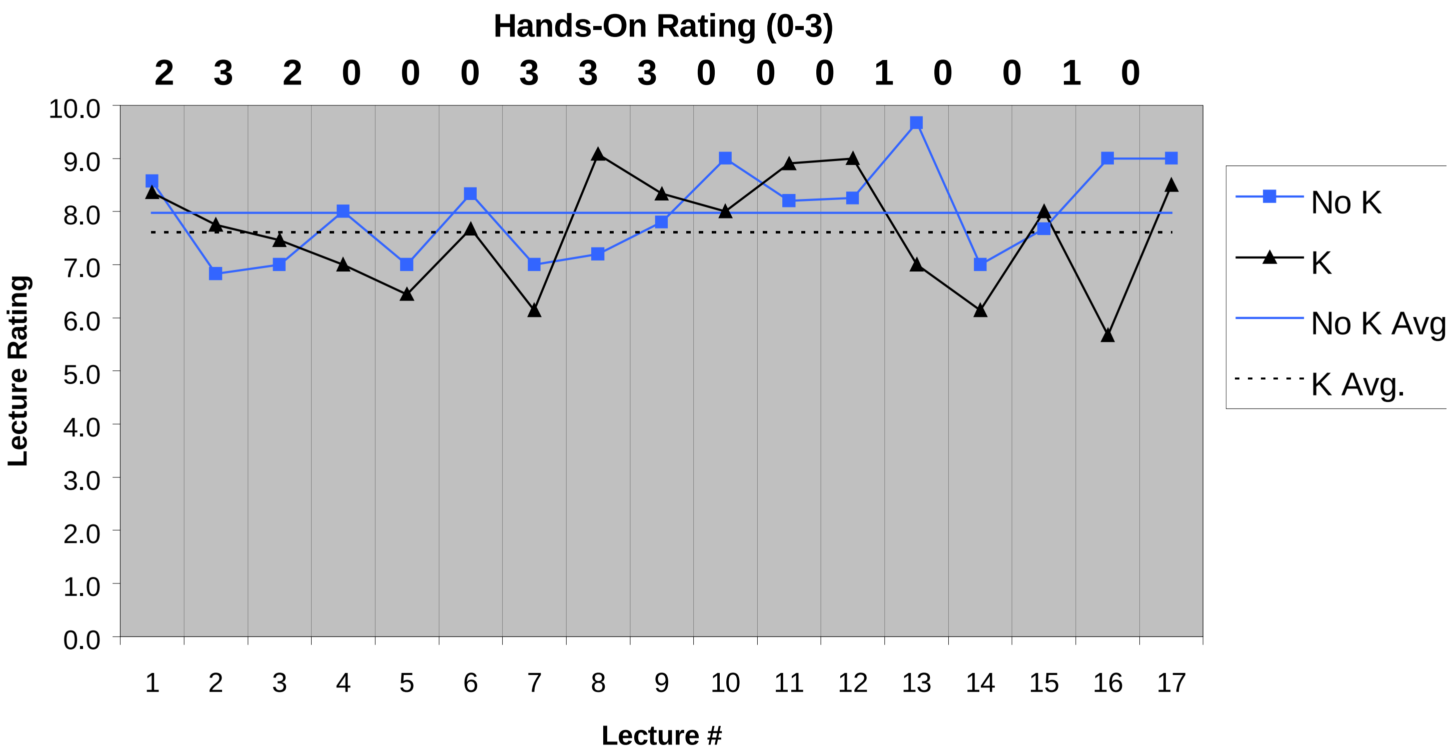
Note: "No-K" students rated hands-on lectures an average of 0.34 standard deviations (13%) **lower** than their "average lesson" while K students rated them 0.1 standard deviations (9%) **higher**.

Fig 5. Hands-On Content: Was it a Good Learning Experience?



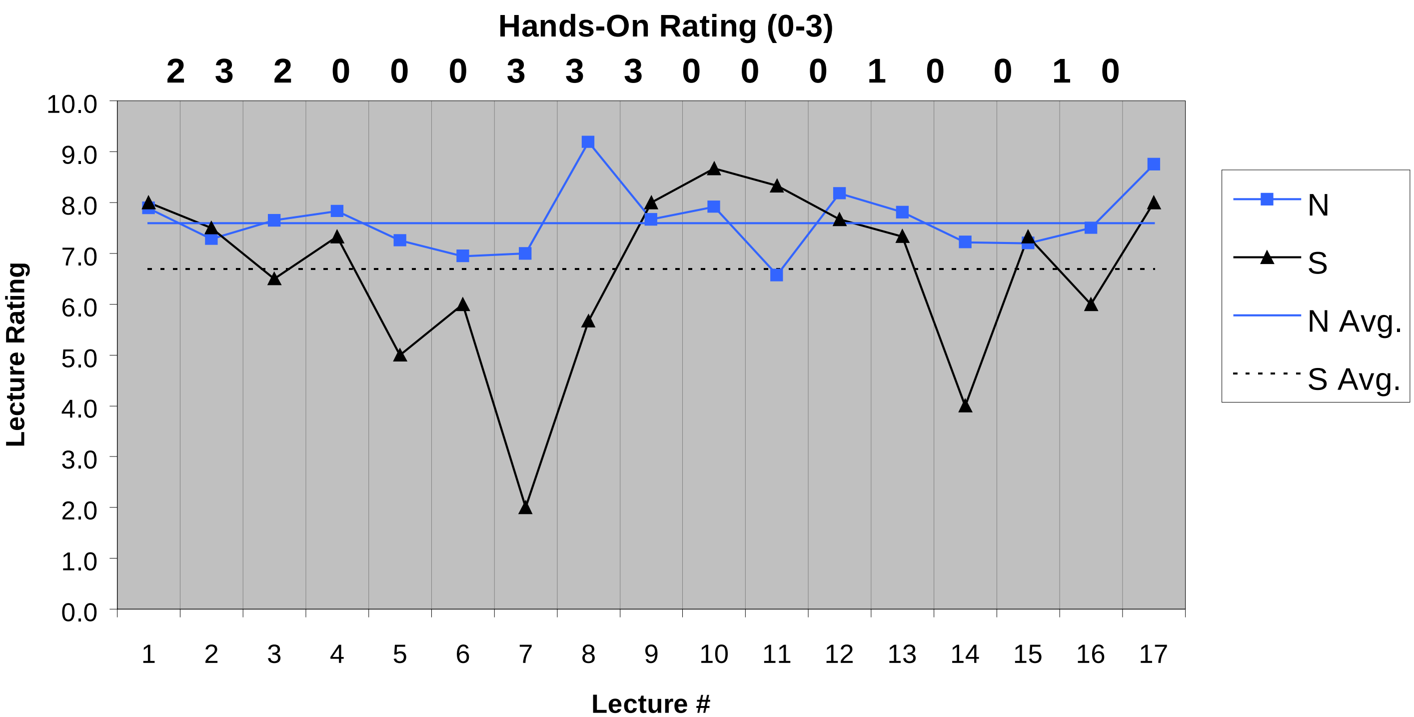
Note: N students rated hands-on lectures the same as their "average lesson" while S students rated them an average of 0.2 standard deviations (8%) **higher**.

Fig 6. Hands-On Content: Was it a Good Learning Experience?



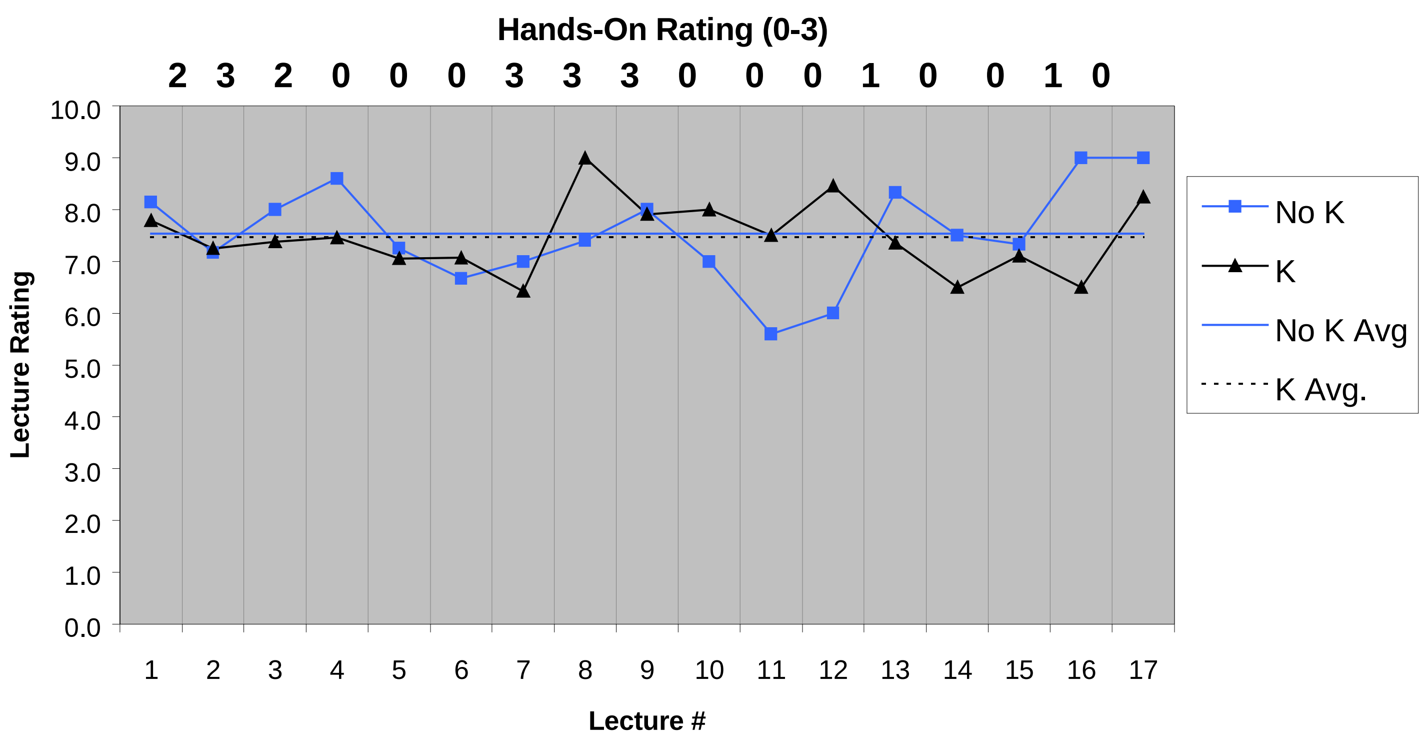
Note: "No-K" students rated hands-on lectures an average of 0.45 standard deviations (17%) **lower** than their "average lesson" while K students rated them 0.06 standard deviations (2%) **higher**.

Fig 7. Hands-On Content: Did it Prepare You to Apply Today's Material to Future Problems?



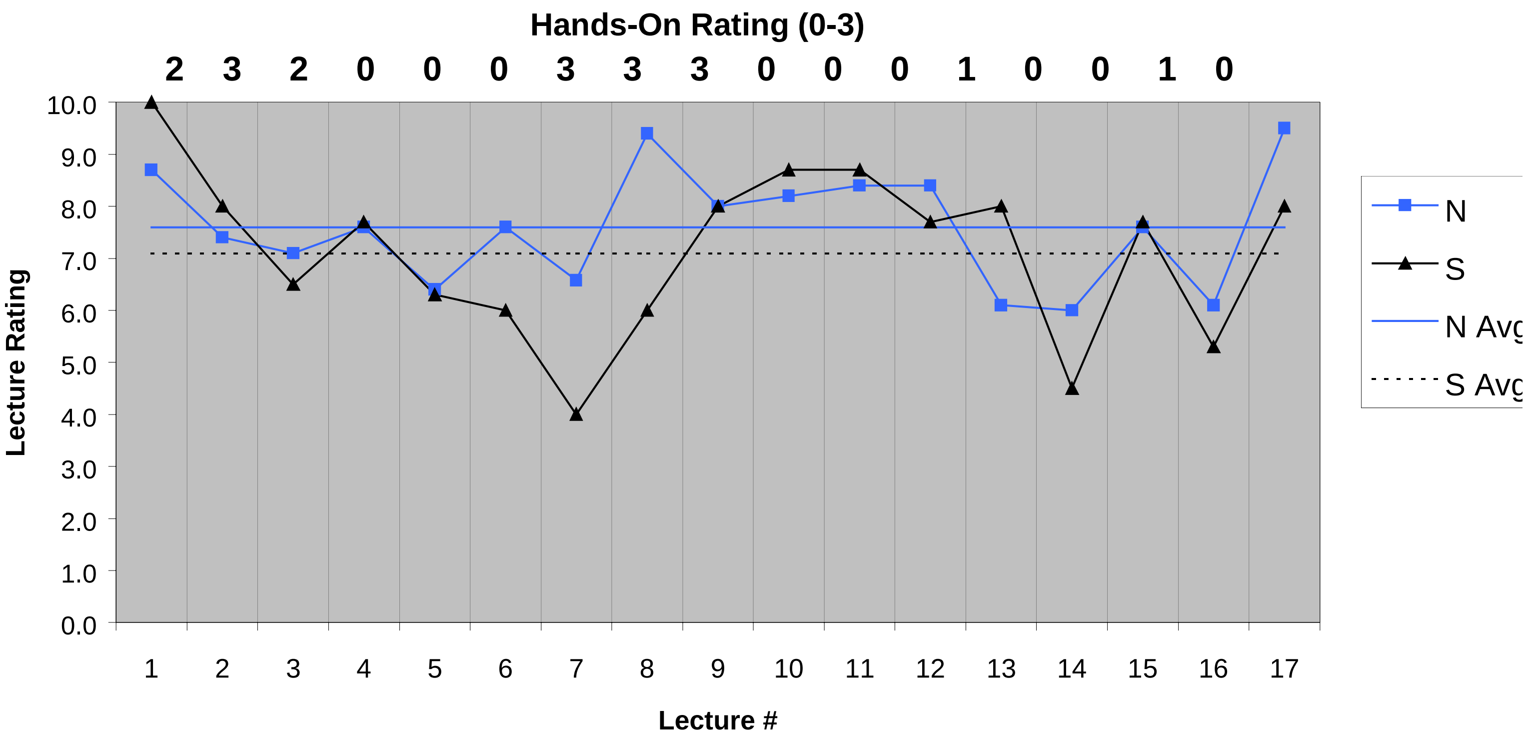
Note: N students rated hands-on lectures an average of 0.20 standard deviations (8%) higher than their "average lesson" while S students rated them 0.22 standard deviations (9%) higher.

Fig 8. Hands-On Content: Did it Prepare You to Apply Today's Material to Future Problems?



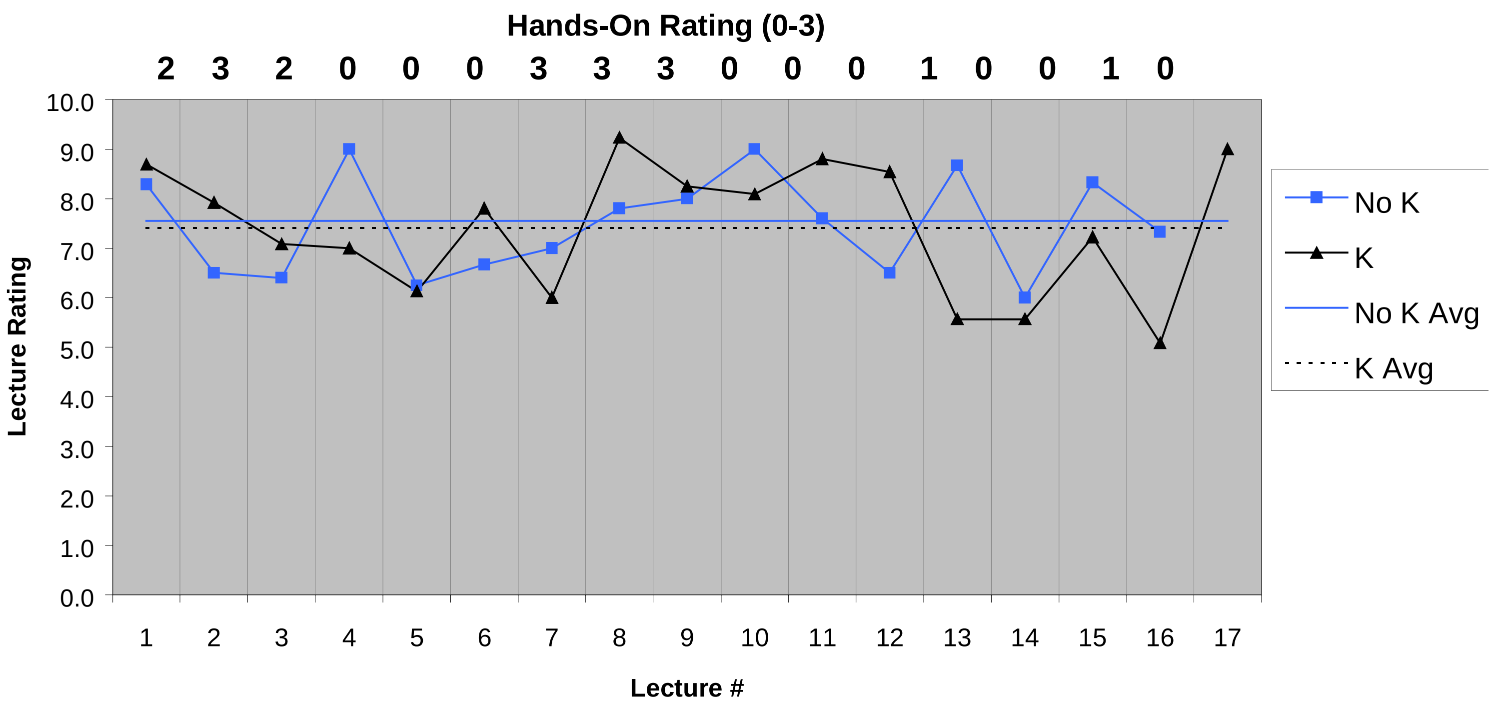
Note: "No-K" students rated hands-on lectures an average of 0.16 standard deviations (6%) higher than their "average lesson" while K students rated them 0.12 standard deviations (5%) higher.

Fig 9. Hands-On Content: Did it Motivate You to Further Explore Today's Concepts?



Note: N students rated hands-on lectures an average of 0..07 standard deviations (3%) higher than their "average lesson" while S students rated them 0.23 standard deviations (9%) higher.

Fig 10. Hands-On Content: Did it Motivate You to Further Explore Today's Concepts?



Note: "No-K" students rated hands-on lectures an average of 0..14 standard deviations (5%) **lower** than their "average lesson" while K students rated them 0.13 standard deviations (5%) **higher**.

4.5 Trends Seen in the Correlation Study

As can be seen from Table 3, when comparing the ratings given by S-types and N-types, the S-types give higher ratings for each of the 4 questions (avg. for all 4 questions = 62nd percentile for S-types and 52nd percentile for N-types). This is a predictable result as S-types should prefer to have the sensory input offered by hands-on content. Note that the differences between the ranking given by S-types and N-types are far more pronounced for question 1 (70th percentile for S-types vs. 48th percentile for N-types) than for the other three questions (avg. for questions 2-4 is 59th percentile for S-types and 54th percentile for N-types). It appears that the questions 2-4, which measure learning, applicability and motivation for further exploration, have a greater appeal to the abstract thinking N-types. It appears that what the N-types are saying is "I don't really find the hands-on content interesting, but it does help me learn and apply the material… and it does motivate me to pursue the topic further". Although it is a worthy goal to have a lecture be "interesting (i.e. question #1), actual lecture objectives are more likely to align with what is measured in questions 2-4. It seems then, that the effect of hands-on material is more pronounced on N-types for the important categories of learning, applicability and motivation for further exploration than anticipated. Also, note that although the ratings overall for the hands-on content are not very far above average (about 57th percentile overall), the lectures where the hands-on content was added have historically been rated far *below* the average. That is the reason why we specifically targeted these lectures for addition of hands-on content. In this light, the overall rating of 57th percentile is a significant achievement.

Data from the K-types and Non-K-types follow a pattern similar to that for S-types and N-types. Specifically, the K-types overall rate the hands-on content higher than do the Non-K-types (avg. for all 4 question for K-types is 55th percentile and for Non-K-types is 43rd percentile). Only for question 3 (Applicability) is that trend reversed and then only by 1%. These results are expected since the K-types should respond favorably to the "Kinesthetic" environment of hands-on content while those who are Non-K-types should not be a favorable to this. It is interesting to note that the differences between K-types and Non-K-types is very pronounced for both questions 1 and 2 (interest and applicability). Recall that the S-types and N-types responded very differently to question 1, but not as differently to questions 2-4. This represents the single biggest difference between the (S vs. N) and (K vs. Non-K) comparisons. Other than this difference, there appears to be an extremely high degree of similarity between the responses of the S-types and the K-types and between the N-types and the Non-K-types.

Note from Figures 3-10 that the data shows that S-types and K-types have a lower mean rating then do their N-type and Non-K-type counterparts. In addition, these figures show the type of spread the data takes. Note that the data for lecture 8 on the question #1, S/N Graph (Figure 3) is outside of a 3 standard deviation band and is therefore discarded. In this case, that data also had only a single student input due to an error in survey collection. The extremely low score on lecture13 in that same figure is not thrown out as the hands-on content for that lecture had a weight of zero, so the data did not affect the hands-on average.

5. CONCLUSION AND ACKNOWLEDGEMENTS

The sophomore Introduction to Design course at the U.S. Air Force Academy has been restructured over the last three semesters. Addition of a reverse engineering / redesign component and incorporation of extensive hands-on content comprise the most significant parts of the restructuring. In order to gage the effectiveness of the restructuring, student feedback has been acquired in the form of quick surveys taken after each lecture. The surveys measure: 1) students' level of interest, 2)amount learned, 3) applicability of the content and 4) motivation to pursue the topic further for each lecture. The results from the surveys were compiled to provide correlation between students' responses and their MBTI and VARK types for the four questions on the survey.

Results show that overall, students positively rated the lectures which contained hands-on content. S-type students were more favorable to the hands-on content than were N-type students and K-type students were more favorable to this hands-on content then were their Non-K-type counterparts. Although certain "types" responded to the hands-on content more favorably then others, overall it is shown that the addition of the hands-on experiences significantly improves design courses.

This work has been partially sponsored by Air Force Office of Scientific Research.

6. REFERENCES

1. Aglan, H.A., Ali, S.F., "Hands-on Experiences: An Integral Part of Engineering Curriculum Reform," *Journal of Engineering Education*, pp. 327-330, Oct., 1996.
2. Behr, Richard A., "Computer Simulations Versus Real Experiments in a Portable Structural Mechanics Laboratory," *Computer Applications in Engineering Education*, Vol. 4 (1), pp. 9-17, 1996.
3. Bonwell, C.C., "Active Learning and Learning Styles," Active Learning Workshops Conference, USAF Academy, Co, July, 1998.
4. Brickell, J.L., Porter, D.B., Reynolds, M.F., Cosgrove, R.D., "Assigning Students to Groups for Engineering Design Projects: A Comparison of Five Methods", *Journal of Engineering Education*, pp.259-262, July 1994.
5. Carlson, L. E., "First Year Engineering Projects: An Interdisciplinary, Hands-on Introduction to Engineering, Proceeding of the ASEE Annual Conference, pp. 2039-2043, 1995.
6. Catalano, G. D., Tonso, K. L., "The Sunrayce '95 Idea: Adding Hands-on Design to an Engineering Curriculum," *Journal of Engineering Education,* pp. 193-199, Jul., 1996.
7. Cooper, S. C., Miller, G. R., "A Suite of Computer-Based Tools for Teaching Mechanics of Materials," *Computer Applications in Engineering Education*, pp. 41-49, 1996.
8. Dunn, R., Dunn, K. Teaching Students through Their Individual Learning Styles: A Practical Approach. Reston, Virginia: Prentice Hall, 1978.
9. Eder, W. E., "Comparisons – Learning Theories, Design Theory, Science," *Journal of Engineering Education,* pp. 111-119, Apr., 1994.
10. Felder, R. M., Brent, R., "Navigating the Bumpy Road to Student-Centered Instruction," *College Teaching,* 44(2), pp. 43-47, 1996.
11. Felder, R. M., Silverman, L. K., "Learning and Teaching Styles in Engineering Education," *Engineering Education*, pp. 674-681, Apr., 1988.
12. Felder, R. M., "Matters of Style," *ASEE Prism*, pp.18-23, Dec., 1996.
13. Fleming, N. D., Mills, C., "Not Another Inventory, Rather a Catalyst for Reflection," To Improve the Academy, Vol. 11, pp. 137-149, 1992.
14. Flori, R. E., "Perspectives on the Role of Educational Technologies," *Journal of Engineering Education*, pp. 269-272, Jul., 1997.
15. Jensen, D. D., "Using MSC-PATRAN for Pre and Post Processing for Specialized FEM Codes which are not in the Standard MSC-PATRAN Library," Proceeding of the MSC World Conference, New Port Beach, CA, June, 1994.
16. Jensen, D. D., "Teaching Finite Elements Using the Software Package PATRAN, Advantages and Drawbacks," Proceeding of the ASEE Pacific Southwest Annual Conference, Sacramento, CA, Oct., 1994.
17. Jensen, D.D. and Pramono , E., "A Method for Teaching Finite Elements Which Combines the Advantages of Commercial Pre and Post -Processing with Student Written Software," *Computer Applications in Engineering Education,* Vol. 6, No. 2, pp. 105-114, June 1998.
18. Jensen, D.D., Murphy, M.D., Wood, K.L., "Evaluation and Refinement of a Restructured Introduction to Engineering Design Course Using Student Surveys and MBTI Data", *Proceedings of the ASEE Annual Conference,* Seattle WA, June, 1998.
19. Jensen, D., Borchert, R., "MSC-Patran Used to Improve Education by Providing Visualization of Stress Concepts," *MSC World,* to appear Feb 1999.
20. Jung, C. G. **Psychological Types, Volume 6 of the collected works of C.G. Jung**, Princeton University Press, 1971 (original work published in 1921).
21. Kersey, D., Bates, M. **Please Understand Me.** Del Mar: Prometheus Press, 1984.
22. Kresta, S. M., "Hands-on Demonstrations: An Alternative to Full Scale Lab Experiments," *Journal of Engineering Education*, pp. 7-9, Jan., 1998.
23. Laurillard, D., "Rethinking University Teaching: A Framework for Effective Use of Technology," Routledge, New York, 1993.
24. Lawrence, G., People Types and Tiger Stripes: A Practical Guide to Learning Styles.

25. Lefever, D. and Wood, K.L., “Design for Assembly Techniques in Reverse Engineering and Redesign,” *ASME Design Theory and Methodology Conference*, Irvine, CA, Paper No. 37 DETC/DTM-1507. 1996.
26. Lumsdaine, M., Lumsdaine, E., “Thinking Preferences of Engineering Students: Implications for Curriculum Restructuring,” *Journal of Engineering Education*, pp. 193-204, Apr. 1995.
27. McCaulley, M. H., “The MBTI and Individual Pathways in Engineering Design,” *Engineering Education*, pp. 537-542, July/Aug., 1990.
28. McCaulley, M. H., Godleski, E. S., Yokomoto, C. F., Harrisberger, L., Sloan, E. D., “Applications of Psychological Type in Engineering Education,” *Engineering Education*, pp. 394-400, Feb., 1983.
29. McCaulley, M. H., “Psychological Types in Engineering: Implications for Teaching,” *Engineering Education*, pp. 729-736, Apr., 1976.
30. Meyer, D. G., Krzyzkowski, R.A., “Experience Using the Video Jockey System for the Instructional Multimedia Delivery,” Proceeding of the ASEE Frontiers in Education Conference,” pp. 262-266, Nov. 1994.
31. Myers, I.B., and McCaully, M.H., Manual: A Guide to the Development and Use of the Myers Briggs Type Indicator, Consulting Press, 1985.
32. Otto, K.N. and Wood, K.L., “A Reverse Engineering and Redesign Methodology for Product Evolution,” *ASME Design Theory and Methodology Conference*, Irvine, CA, Paper No. DETC/DTM-1523, 1996.
33. Otto, K., Wood, K.L., Murphy, M.D., Jensen, D.D., “Building Better Mousetrap Builders: Courses to Incrementally and Systematically Teach Design,” *Proceedings of the ASEE Annual Conference*, Seattle WA, June, 1998.
34. Ramirez, M. R., “The Influence of Learning Style on Creativity,” 1993 ASEE Annual Conference Proceeding, pp.849-853, 1993.
24. Regan, M., Sheppard, S., “Interactive Multimedia Courseware and the Hands-on Learning Experience: An Assessment,” *Journal of Engineering Education*, pp. 123-131, Apr., 1996.
35. Rosati, P., Yokomoto, C. F., “Student Attitudes Toward Learning: By Seniority and By Type,” 1993 ASEE Annual Conference Proceeding, pp. 2038-2043.
36. Sheppard, S., Regan, D., “Bicycle Multimedia Courseware: Formative In-depth assessment Report,” Center for Design Research Internal Report, Stanford University, Dec., 1995.
37. Smith, A. B., Irey, R. K., McCaulley, M. H., “Self-Paced Instruction and College Student Personalities,” *Engineering Education*, pp. 435-440, Mar., 1973.
38. Solomon, B., in **Keys to Success**, by Carol Carter and Sara Lyman-Kravits, Prentice Hall, 1995.
39. Ullman, D.G., The Mechanical Design Process, McGraw Hill, 1992.
40. Wankat, P. C., Oreovicz, F. S. **Teaching Engineering.** Toronto: McGraw Hill, 1993.
41. Wilde, D.J., “Mathematical Resolution of MBTI Creativity Data into Personality Type Components”, *Design Theory and Methodology*, ASME, DE-Vol. 53, pp37-43, 1993.