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DESIGN IMPLEMENTATION AND ASSESSMENT OF A SUITE OF MULTIMEDIA AND HANDS-ON ACTIVE LEARNING ENHANCEMENTS FOR MACHINE DESIGN

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ABSTRACT

Over the last eight years, the Machine Design courses at the United States Air Force Academy and at the University of Texas, Austin have evolved through the development, implementation and assessment of extensive active learning methods to the curriculum. In particular, the courses were evolved to include extensive hands-on projects that are integrated throughout the course as well as a significant multimedia component. The hands-on educational innovations, which promote experiential investigation using hands-on devices such as remote controlled cars, Lego RoboLab, and reverse engineering of consumer products, have received very positive assessment. The multimedia, which includes extensive foundational content on Mechanics of Materials as well as a separate multimedia experience for learning about planetary gear systems, has also been assessed and received very affirmative feedback. The assessment of these active learning educational innovations has been multifaceted. Quantitative components of the assessment have included student end-of-course critiques, homework, specific exam questions and survey data. Qualitative assessment has been achieved through focus groups as well as both written and verbal feedback from students and professors using the active learning aids. Although the majority of the assessment has been positive, we have also received important constructive criticism during the development of these educational enhancements. The "iterative" development of these active learning techniques has involved responding to these criticisms and reassessing the program's effectiveness. In this paper, we first provide an overview of the previous work done in this area, then move on to show new developments and assessment. In particular, new assessment, which is correlated with Myers Briggs personality types, is reported showing results of the current integrated use of active learning techniques, including hands-on and multimedia experiences. In this light, the current paper should work as a roadmap for others who desire to integrate active learning into their courses, whether they are courses in Machine Design or not.

1.0 INTRODUCTION AND GOALS

Most universities that teach mechanical engineering include a machine design or machine elements course as part of the curriculum. Such courses usually focus on the material covered in classical texts such as those of Spotts [1], Shigley [2], or Juvinall [3]. These textbooks, for the most part, cover the fundamentals of solid mechanics, factors of safety, fatigue issues, and the analysis of discrete machine components.

At the University of Texas, Austin (UTA), undergraduate mechanical engineering students enroll in a machine design class during the early part of their junior year. This course, known as ME 338 – Fundamentals of Machine Elements, focuses on a balance between solid mechanics theory and a study of machine elements and subsystems, such as gears, bearings, and springs. At the US Air Force Academy (USAFA), cadets in the mechanical engineering program take their machine design course during the second semester of their junior year. This course is referred to as ME 370 – Machine Design, and it also divides the course material between basic theory and a study of machine elements. Thus, classically, emphasis of machine design courses has been on solid mechanics principles applied to individual machine elements.

The emphasis of machine design courses has its roots in material from the 1950's. These roots are important and have evolved from the research in the field of mechanisms and machines. However, the classical emphasis of teaching machine design raises a number of issues in the contemporary engineering curriculum. For example, today's students are no longer tinkerers; often preferring to spend discretionary time on video-oriented activities. This characteristic often results in a "disconnect" between the theory in the course and the reality of implementing machine elements in a device. Due to this disconnect, students are often not successful in implementing the knowledge in follow-on design courses, such as their capstone design course.

Likewise, students are not given many opportunities for making assumptions and performing estimation. While textbook problems may be repeated and solved by the students, they do not demonstrate an ability to apply the material to simple machines, such as mechanical toys or electromechanical kitchen appliances. The skills of taking a "real world" device, dissecting and filtering the information, and simplifying the results are not emphasized in the classical approach.

A companion issue concerns the lack of a systems design approach in many machine elements courses. Quite often elements are considered singularly. Their combination and interfaces are not dealt with in terms of analysis or design. The introduction of a real world device provides a platform for a study of systems design capability.

Different learning styles across the student body raise a complementary issue concerning the pedagogy of machine design instruction. Past student evaluations at UT and USAFA (when the courses emphasize mechanics of material theory and a broad survey of machine elements) show that the interest in machine design courses is not as high as desired or expected. Since machines are fundamental to mechanical engineering, one would expect machine design to be one of the most popular courses in the curriculum. However, past student evaluations do not support this expectation. An analysis of the evaluations shows that students are seeking a more hands-on approach and would also like to have the content portrayed in multimedia format [4]. This approach allows them to learn intrinsic aspects of the machine elements, not just the theory of how they are designed. The pedagogical literature makes it clear that inclusion of this active learning content enhances learning [5,18]. However, a detailed study that correlates different types of students with their preferred manner of learning has not been accomplished. Our choice for defining this student "type" is the use of the Myers Briggs Type Indicator (MBTI). Students' MBTI types are therefore correlated below with their survey responses indicating their preference for specific types of active learning activities including multimedia and hands-on devices.

Further motivation for promoting hands-on, active learning activities is illustrated in Figure 1. The figure shows Kolb's model of learning [18,25-27], embodied by a cycle that begins with concrete experience, proceeds with reflective observation and conceptualization, and ends, before restarting, with active experimentation. By studying and dissecting current machines, the physical components may be directly experienced with all senses. Design methods may then be used to hypothesize current functions, and conceptualize new functions and/or solutions to the current configuration. Observation and active experimentation with the current and refined concepts may then be executed, realizing mental ideas into physical embodiments. The process may then begin again, where further iteration enhances and cements learning, as well as actual product improvements.

The Kolb model (Figure 1) swings the pendulum of learning engineering from an emphasis of generalization and theory to a balance encompassing all modes of learning [26]. Engineering education inherits an equal focus on experiential activities. Without this approach, no concrete experience exists to ground learning and build a solid foundational understanding. The grounding in current machines helps nurture our interest for understanding the way things work and for making devices work better.

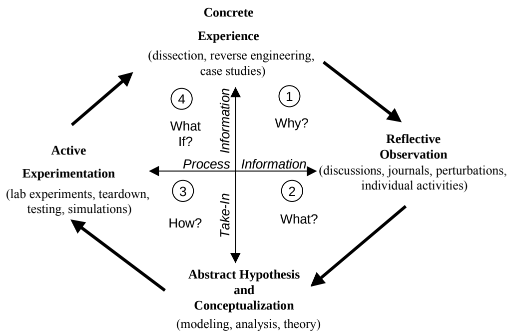

Figure 1. Kolb's Model of Learning [26]

1.1 Need and Goals

Identification of these issues in traditional machine design courses leads to the following statement of need: "create a active learning environment for Machine Design instruction, including hands-on and multimedia content, evolving the purely analytical focus of the past." Supporting goals for this need include the following:

1. develop activities where students manipulate the components they are studying, with emphasis on familiar devices. A systems approach will then be created for teaching machine design, where elements are not studied in isolation and a suite of active learning techniques are used in tandem;
2. add project-oriented design components in the course, both machine layout and analysis; add team assignments to promote active learning through peer interaction and questioning;
3. add multimedia content; redesign the course to better span the known space of preferred styles of interaction as measured by MBTI and;
4. assess the effects of these changes as measured by student feedback and correlate the assessments with student MBTI types.

The remainder of this paper addresses these goals as they have been implemented in our curricula.

2.0 PREVIOUS WORK

Of the four specific goals listed above, goals one (1) and two (2) have been implemented and reported on in our previous publications [4-7,10,15,20-21,24]. The content related to goal 3 has been developed previously in beta form only but is significantly refined for the current work. Activities related to goal 4 are new to this study. Activities that have been implemented previously (related to goals 1 and 2) are reviewed below for context and completeness. Then activities related to goals 3-4 are described in detail.

2.1 Goal 1

Goal one (1) is to "develop activities where students manipulate the components they are studying, with emphasis on familiar devices". This goal has been achieved through the introduction of four different platforms: remote controlled cars (Figure 2), Lego Mindstorm devices (Figure 3), reverse engineering of everyday electro-mechanical products (such as toys, kitchen appliances, hardware tools, and sporting aids), and show-n-tell activities throughout the semester.

Figure 2: Remote Controlled Car Project

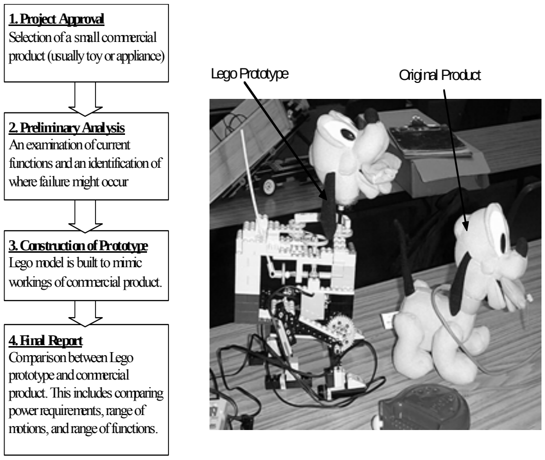

Figure 3. Project Tasks in the Lego "Reverse Engineering" Project: Comparison of Walking Dog Prototype and its Commercial Counterpart

Electro-mechanical products, Lego Mindstorms and RC cars have extensive component combinations that can be analyzed using techniques learned in the course. Examples include clutches, gears, fasteners, springs, linkages and shafts. Using a combination of analysis and testing for both performance and failure, it is possible to use these mechanical systems to help students appreciate the value of analysis and the inherent limitations. The specific details of implementation and assessment for the reverse-engineered products, RC car and Lego Mindstorm systems are included in the reference [4]. In the current work, this assessment has been correlated with MBTI data as reported in the assessment section below.

2.2 Goal 2

Goal two (2) is to "add project-oriented design components in the course, both machine layout and analysis; add team assignments to promote active learning through peer interaction and questioning". The accomplishment of this goal is also reported in [4]. Various projects have been used to facilitate this goal. An example is the slip clutch on the RC car. The RC car affords a unique opportunity for students to experiment with a simple, single friction disk clutch. The actuating force on the clutch disk can be adjusted by means of a compression spring and a single screw and allows for analysis of the axial force on the disk, torque capacity, and resulting slippage of the drive mechanism. The class project shown in Figure 4 was accomplished in parallel with class lectures on clutch and brake machine components. Explicit assessment of these projects has been gathered and analyzed, and has also been correlated with MBTI data. These results are provided below in the assessment section.

RC CAR CLUTCH ANALYSIS PROJECT

DATA:

- The RC car electric motor has a maximum output of 0.25 HP at 15,000 RPM.
- This power is transferred through a pinion and drive gear to the car's clutch mechanism.
- The clutch is a single molded Rubin disc with a coefficient of friction of 0.36

FIND:

- Determine the needed initial force delivered by the clutch spring to insure no slippage will occur (factor of safety =1.0)
- Determine the force needed after the clutch has broken in
- Is this clutch designed for maximum torque transfer? Why or why not?

Figure 4. Clutch System Analysis Project

3.0 CURRENT CONTENT AND ASSESSMENT

3.1 Goal 3

Goal three (3) is stated as "add multimedia content; redesign the course to better span the known space of preferred styles of interaction as measured by MBTI". This goal has been partially fulfilled by our previous multimedia development projects [6,24]. However, the current embodiment of the course more fully integrates the multimedia into the Machine Design class in an attempt to motivate the full span of students as measured by their MBTI preferences. Two software packages are being used to facilitate this goal. The first is called Vis-MoM (for Visual Mechanics of Materials), and the second is named PG-Sim (for Planetary Gear Simulation). Both courseware packages were written in-house at the US Air Force Academy. Vis-MoM was initially developed under contract with MSC.Software Corporation and has since been significantly revised.

The interactive multimedia courseware Vis-MoM is designed to span the space of learning styles by providing extensive visualization and interactive content as well as thorough, step-by-step example problems. We have previously shown that these particular features of our courseware correspond well to a full span of student learning styles [6]. Vis-MoM is designed to increase motivation through extensive use of real-world examples and an interactive, thought-provoking learning environment. We show the open-ended nature of the subject by inclusion of open-ended design problems for each topic.

Vis-MoM is a module-based interactive learning program. The visualization modules are designed to provide an extensive multimedia exposure for the six foundational application areas covered in a Mechanics of Materials course and depicted on the Vis-MoM title page shown in Figure 5. In order to provide in-depth coverage, the Vis-MoM courseware encompasses over 125 multimedia pages, hundreds of pictures and graphics, numerous animations and movies, and extensive interactions. The topic coverage includes background information, theory, procedures for analysis, detailed example problems, suggested workout problems and comprehensive open-ended interactive design problems.

Sections of each courseware module contain specific consideration of concepts, which are either fundamental to further understanding of basic concepts or are traditionally difficult to comprehend without extensive study. Interactivity has been and continues to be a major focus in the development of Vis-MoM, and its importance is continually reinforced by the assessment data received every semester. Interactivity and its integration to visualization are pervasive throughout the modules and are focused on meeting specific learning objectives. For each topic, a select set of concepts are visually portrayed (e.g. the cross-sectional distribution of bending stress) and then interactively reinforced in the example problem and again in the design problem. This approach promotes increased conceptual understanding by repetition of fundamental principles while incrementally increasing the level of detail.

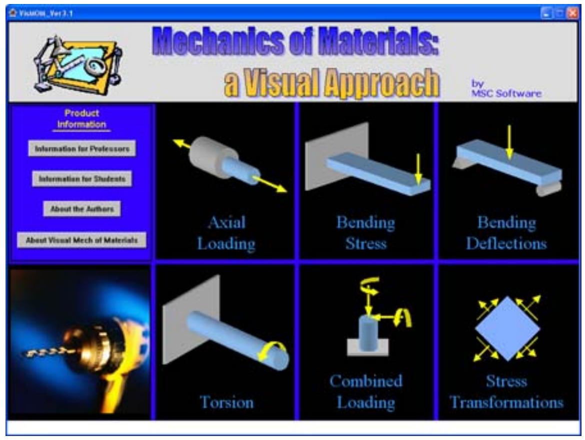

Figure 5. Vis-MoM Courseware Title Page

From the outset, a primary consideration in the creation of Vis-MoM has been educational theory and learning styles. Each of the courseware modules contains a section titled *"Example, Workout & Design Problems"* which is intended to demonstrate and allow application of the theory.

Our specific goals for the incorporation of Vis-MoM into the Machine Design Course were to: (1) balance material covered during class time with outside reinforcement and review (free up 2-3 lectures for covering additional Machine design material) and (2) ensure that the students still have an ability to apply the foundational material from Mechanics of Materials. Specific assignments were given very early in the course which required the students to use the Vis-MoM software to review critical concepts from Mechanics of Materials. This review material is then not covered during class time.

Some of our assessment of Vis-MoM has been in the form of quantitative data obtained from evaluations specifically for this project, and some has been simply insightful suggestions from the professors and students who have used the various versions of Vis-MoM. Dozens of professors and hundreds of students have provided qualitative and/or quantitative feedback on the various versions of Vis-MoM. Overall, the Vis-MoM courseware has been well received. In particular, the latest version has received extremely high marks by professors and students alike and has been quantitatively shown to enhance learning [4]. Assessment specifically correlated to MBTI and taken from the most current version of Vis-MoM is provided in the assessment section below.

The second multimedia courseware package we have implemented in this work is called PG-Sim [24]. The purpose of PG-Sim is to demonstrate the operation of a simple planetary gear set and illustrate its use in an actual application, an automatic transmission. There are a number of advantages of the simulation over a textbook-only presentation [14,23]. A primary advantage is that PG-Sim is dynamic; it shows moving parts. Textbooks typically present schematics of transmissions that show how components are connected, not their relative motions. In addition, PG-Sim is interactive, highly visual and illustrates a real-world application.

Figure 6 shows the user interface where audio visual interleaved (avi) files are activated by clicking on certain command buttons. Other command buttons display joint photographic experts group (jpeg) files that give explanations of, for example, gear kinematics or the Chrysler 42LE transmission, see Figure 7. Along the bottom left of the user interface is the command button set that activates the simple planetary gear simulations. A planetary gear set is comprised of a sun and ring gear and several planet gears. The planet gears are mounted on a carrier. The student can review the laws that govern planetary set motion directly in the software. The operation of a single planetary set is simulated once the user chooses one of the sun, ring, or carrier components for the driving or input gear and a different component for the driven or output gear. The third component, by default, is the held or fixed component. Six different combinations can be simulated depending on the user's choice for the input and output components. Each of these six combinations produces a different gear ratio and determines if the system provides for a forward or reverse gear.

Along the right side of the interface are the command buttons that activate the 42LE automatic transmission simulations. The user chooses one of three radio buttons for each of the five transmission gears. As the simulation progresses, some of the outer splines become translucent thus revealing the compound planetary gear in motion within (Figures 7a and 7b).

Finally, the smaller 42LE grouping of command buttons at the bottom of the interface gives some additional information on the automatic transmission. The "Explode" command button activates a simulation that shows how the transmission components fit together by showing the components disassembling. The "42LE Kinematics" button provides an overview of the transmission's kinematics and the resulting gear ratios.

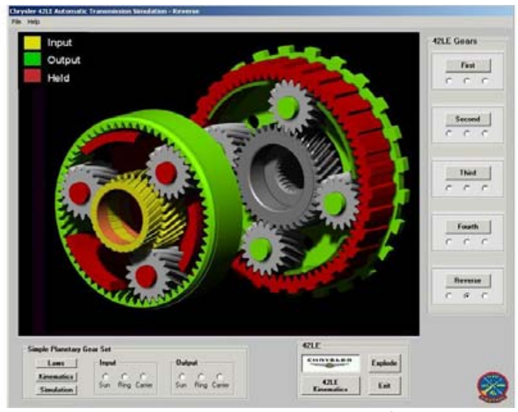

Figure 6 – PG-Sim User Interface

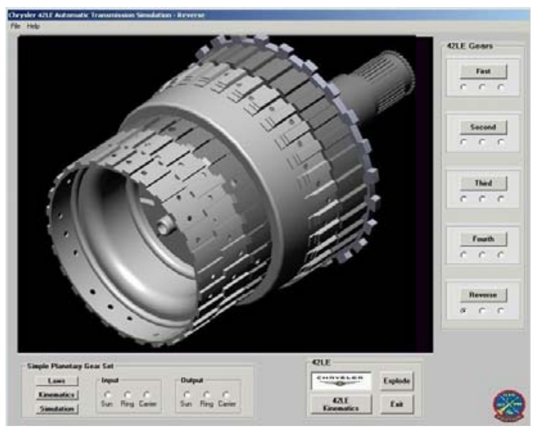

Figure 7a
PG-Sim 42 LE Automatic Transmission

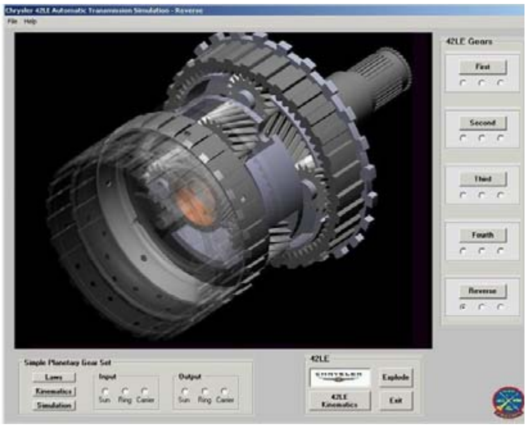

Figure 7b
Dissolving 42 LE Automatic Transmission

It is well established that different students learn in different manners [7,18-19]. PG-Sim provides a learning environment that has the following features: (1) dynamic, the gears move to show their interaction, (2) highly visual, (3) interactive, there are 25 different commands for the student to interact with PG-Sim, and (4) based on a real-world device, the 42LE is in current use in a number of Chrysler vehicles. These different features allow students who learn in different ways to "find their niche." Felder specifically advocates this type of learning experience when he advises "teaching across the spectrum of learning styles" [19]. In the case of PG-Sim, students who learn visually, for example, have ample opportunity to do so using the software. The real-world application shown in PG-Sim provides increased motivation in certain groups of students. The interactivity and dynamic nature of PG-Sim creates an active learning environment that appeals to many types of students as well. Quantitative assessment data from the latest iteration of using PG-Sim including some correlations with MBTI data are included in the assessment section below.

3.2 Goal 4

Goal four (4) is stated as "assess the effects of these changes as measured by student feedback and correlate this with student MBTI types". For contaxt and completeness, a short overview of MBTI is provided below.

The MBTI type indicator includes four categories of preference [10,20,28-34]. 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.

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, as adapted from [34], gives a brief overview of the four MBTI categories.

	Manner in Which a Person Interacts With Others		
E	Focuses outwardly. Gains energy from others.	Focuses inwardly. Gains energy from cognition	I
	EXTROVERSION	INTROVERSION	
	Manner in Which a Person Processes Information		
S	Focus is on the five senses and experience.	Focus is on possibilities, 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 decisions.	Focus on process oriented decision-making.	P
	JUDGEMENT	PERCEPTION	

Use of student's and professor's MBTI data for purposes of improving engineering courses has been investigated previously. McCaully et al., in conjunction with the Center for Applied Psychological Type, have determined MBTI type for thousands of engineering students at various universities. These data have been analyzed for application to student learning as well as for possible use in career counseling and student retention strategies [31-33]. Other examples include using MBTI to develop self instruction materials, using MBTI comparisons between freshman and senior students to determine the change in preference brought about during the four years of engineering curriculum and work which has shown the potential to increase academic success of struggling students by strengthening their non-preferred areas.

In terms of goal four (4), our purposes in this current work are to investigate correlations between specific MBTI types and those students' responses to different types of active learning content. The assessment section below describes these results.

3.3 Assessment

The assessment data reported in the current work is based on data taken from students after completion of the Machine Design course at USAFA. Students were asked to voluntarily provide feedback by filling out surveys. Students were rewarded for filling out the surveys by dropping their lowest homework score if the survey was complete. There were 25 homeworks during the semester, so completing a survey allowed for an increase of homework percentage of 4%. Approximately 500 data points were provided by students to complete these data. The data are broken into three parts: (a) general assessment of active learning techniques, (b) assessment of the Vis-MoM courseware and (c) assessment of the PG-Sim courseware. Separate assessment instruments (surveys) were developed for each of the three areas. The instruments contained 13 questions covering the general active learning techniques and 9 questions each for the Vis-MoM and PG-Sim courseware packages. Each question was designed to uncover the perceived effectiveness of a specific aspect of the course. For example, one of the questions in the "general assessment" survey states "I found the use and analysis of the RC car to be helpful in understanding the course material." Students were asked to respond to using a modified Likert scale which ranged from 0 to 4 with meanings defined as: 0=disagree, 1=very slightly agree, 2=somewhat agree, 3=mostly agree, and 4=totally agree. A high score assigned by students to a particular aspect of the course indicates that students rated that aspect as highly effective. Lower scores indicated that students did not find that aspect as effective. Questions from the three surveys are recorded in Tables 2 and 3. Student scores are averaged and reported in Tables 4-7.

Table 2
Questions for the General Course Survey

0=disagree 1=very slightly agree 2=somewhat agree 3=mostly agree 4=totally agree
a) The courseware helped me learn about planetary gear systems (basic mechanics).
b) The courseware was well organized.
c) The courseware was easy to use.
d) The navigation through the courseware was intuitive.
e) The courseware content was interesting.
f) The content in the courseware was presented in a manner that made it easy to understand.
g) The details (like equations) in the courseware were presented well.
h) I would prefer to use this courseware to learn about planetary gear systems (basic mechanics) over the text's presentation.
i) Using the courseware increased my interest level in planetary gear systems (basic mechanics).

Table 3
Questions for the PG-Sim Survey
(Vis-MoM version in parenthesis)

0=disagree 1=very slightly agree 2=somewhat agree 3=mostly agree 4=totally agree
a) I found the textbook to be helpful
b) I found the in-class instruction (lectures) to be
c) I found the 2 projects to be helpful
d) I found the use and analysis of the RC car to be helpful
e) I found that doing the homework was helpful
f) I found the work I did with others (projects or collaborative h.w.) to be helpful
g) I found the work I did by myself to be helpful
h) I found the use of hands-on examples to be helpful
i) The fact that this class is very applied appeals to me.
j) The fact that this course's content is imprecise and non-theoretical does not bother me.
k) I would not have preferred a more hands-on approach to learning how to analyze machine components.
l) I would not have preferred a more theoretical approach to learning how to analyze machine components.
m) I would highly recommend this course to my fellow cadets

The survey response data are correlated with both MBTI results and with students' grades. The MBTI data were derived from the instrument available on-line at http://www.humanmetrics.com/cgi-win/JTypes2.asp.

In Tables 4-7 students' responses are given as averages for each question and then as percentiles for each of the eight possible MBTI letters. For example, in Table 4, it can be seen that the average student response for question "a" ("I found the textbook to be helpful in understanding the course material") was 2.4 (approximately midway between "somewhat agree" and "mostly agree"). The percentiles for each of the 8 possible MBTI letters are computed according to standard Gaussian statistical formulas. For example the "extroverts" (MBTI E-type) had an average response to question "a" of 2.6. The standard deviation of all student responses to question "a" was 0.8. This means that the MBTI E-types answered question "a" $\frac{0.8}{2.6} = 0.308$ standard deviations on the high side of the average response of 2.4. Based on the Gaussian (normal) probability function, this response is the 62nd percentile response (62% of the data falls below this value). Each of the 13 questions in Table 4 and the 9 questions in Tables 5 and 6 show these percentile results for each MBTI type. An average for each column (MBTI type) is then calculated in the bottom row of each of Tables 4-6.

Table 4 - Responses to General Survey Questions

TOPIC (see table 2)	Avg.	Percentiles							
		E	I	N	S	F	T	J	P
(a) text	2.4	62	28	63	33	53	50	55	21
(b) lectures	3.5	43	68	51	51	37	57	53	40
(c) projects	3.1	58	30	56	38	59	44	49	46
(d) RC car	3.2	55	42	63	32	49	51	52	42
(e) hw	3.3	44	56	50	45	20	61	56	8
(f) collaborative work	3.2	49	49	64	28	49	48	49	43
(g) individual work	3.2	48	50	55	40	34	55	54	16
(h) hands-on	3.7	64	22	43	57	37	54	49	45
(i) applies	3.8	47	54	44	57	23	61	52	32
(j) not too imprecise	2.1	52	54	55	49	33	61	57	27
(k) enough hands-on	1.8	48	54	56	41	49	54	53	29
(l) enough threory	3.0	53	39	44	54	22	61	56	10
(m) recommend course	3.0	52	52	61	39	58	49	50	66
AVERAGE	3.0	52	46	54	43	40	54	53	33

Note first from Table 4 that the overall average score for all the questions on the general course survey was 3.0. This average means that the students, in general "mostly agree" that the various learning aids are helpful. The lowest average is a score of 1.8 for the question of whether there is enough hands-on content in the course. This is noteworthy and, at least for the authors, surprising as this class is one of the most hands-on courses we offer. Evidentially the students have a virtually insatiable appetite for this type of content! It is somewhat redeeming to see that the students give the two highest overall ratings to the hands-on content and the applied nature of the content.

Examining more details form Table 4, in terms of the extroverts (E-type) vs. the introverts (I-type), two surprising results are the relative equity in the percentile ratings for collaborative work (topic "f") and those for the individual work (topic "g"). One would expect that the E-types would prefer the collaborative work, and the I-types would prefer the individual work. However the percentile rankings for individual and collaborative work for both E-type and I-types are all within 2 points of 50%. One would also assume that the I-types would have a more favorable opinion of the text (topic "a"). However the E-types rated the text's effectiveness in the 62nd percentile and the I-types rated it in the 28th percentile. One possible explanation for this result may be that the extroverts only used the text for example problems but not for daily reading. The strongest differential between the E-types and I-types occurs for the "hands-on" category (topic "h") where the E-types give a 64th percentile ranking and the I-types give a 22nd percentile ranking.

Note from Table 4 that the S-type (sensors) rate the hands-on content (topic "h") in the 57th percentile and would even prefer more hands-on content as shown by the percentile ranking of 41st for "enough hands-on" (topic "k"). This is in contract to the 43rd percentile ranking given by the N-types (intuitors) for hands-on content and the 56th percentile ranking for having "enough hands-on" content. These rankings are in clear agreement with conventional wisdom that says that S-types prefer to learn through sensory input (hand-on for example) and N-types learn more from theoretical approaches. In fact the N-types rank the category of "enough theory" (topic "l") at 44th percentile and the S-types rank it at 54th percentile.

Recalling that the T-types (thinkers) prefer content communicated in a logical fashion, it is not surprising that Table 4 shows the T-types percentile rankings for "lectures" (topic "b") and "homework" (topic "e") to be 57th and 61st percentile respectively while the F-type (feelers) give these categories 37th and 20th percentile respectively. What is surprising is that the T types rank the "not too imprecise"(topic "j") category with a 61st percentile while the F-types give it a 33rd percentile. One would expect that the T-types would be quite frustrated with this imprecision while it would not be as significant for the F-types. Possibly the perceived reverse in the rankings for this question are due to the wording of the question. Note from Table 2 that the question uses the word "bother" to describe a *feeling* related to the imprecise nature of the course content. Possibly the T-types are not as "bothered" simply because they are not as feeling-oriented as the F-types are in general.

Finally note that the J-types rate both the "homework" (topic "e") and the "individual work" (topic "g") much more highly (56th and 54th percentile respectively) than do the P-types (8th and 16th percentile respectively). The low rankings from the P-types in this category are expected as homework and individual work have solid deadlines which, if not met, result in lowered grades. P-types characteristically dislike deadlines with consequences far more than do J-types.

Table 5 - Responses to PG-Sim Survey Questions

TOPIC (see table 3)	Avg.	Percentiles							
		E	I	N	S	F	T	J	P
(a) helped me learn	3.5	51	47	53	47	47	53	43	82
(b) well organized	3.4	49	57	53	47	47	53	60	8
(c) easy to use	3.5	51	47	41	60	60	41	51	47
(d) navigation	3.1	55	24	53	46	62	40	55	24
(e) interesting content	3.8	55	26	58	40	26	71	55	26
(f) easy to understand	3.2	52	37	53	46	37	61	52	37
(g) details (equs)	3.2	47	65	37	65	37	61	52	37
(h) better than text	3.6	44	79	58	41	41	58	44	79
(i) increased interest	3.5	50	48	52	48	31	67	46	73
AVERAGE	3.4	50	48	51	49	43	56	51	46

Table 6
Responses to Vis-MoM Survey Questions

TOPIC (see table 3)	Avg.	Percentiles							
		E	I	N	S	F	T	J	P
(a) helped me learn	2.7	66	38	66	1	66	44	47	66
(b) well organized	3.1	65	39	65	1	74	40	46	74
(c) easy to use	3.0	69	35	65	1	78	38	45	78
(d) navigation	3.1	55	46	64	2	72	41	46	72
(e) interesting content	3.1	43	55	59	9	22	62	51	43
(f) easy to understand	2.7	60	43	65	1	60	46	48	60
(g) details (equs)	2.4	71	34	65	1	71	41	46	71
(h) better than text	2.1	36	60	46	74	46	52	46	74
(i) increased interest	1.9	57	45	57	15	57	47	41	91
AVERAGE	2.7	58	44	61	12	60	46	46	70

Tables 5 and 6 show data for the multimedia courseware PG-Sim and Vis-MoM respectively. Note from Table 5 that PG-Sim received an impressively high overall ranking of 3.4 (bottom of 2nd column). In particular the 3.8 ranking for "interesting content" (topic "e") indicates that the software is being well received by the students. The slightly lower ratings for Vis-MoM (Table 6) may be due to the fact that the students used this courseware for an extensive homework set early in the semester intended to force them to comprehensively review basic mechanics of materials. This assignment took significant effort. Still, the overall ranking of 2.7 indicates that the Vis-MoM is also well-received by the students.

It is interesting to note in both Tables 5 and 6 that the introverts (I-types) prefer the courseware to the text (topic "h") far more strongly than do the extroverts (E-types). This result is consistent with the previous data in Table 4 that showed the I-types were not as favorable to the text as the E-types are. Note also that the T-types rank the "interesting content" (topic "e") very highly for both PG-Sim (71st percentile) and Vis-MoM (62nd percentile) while the F-types rank the "interesting content" comparatively low at 26th percentile for PG-Sim and 22nd percentile for Vis-MoM. Evidently the courseware's linear organization appeals to the T-types desire for structure. Finally, note in Table 6 that the S-types ranked the Vis-MoM software extremely low. This is an outlying set of points due to the fact that, although, in general, dozens of students took these surveys, not every student took every survey. In the case of the Vis-MoM survey, only one S-type student took the survey and he/she had a very negative impression of the courseware.

Comment [klw1]: Dan, I don't understand this discussion in the paper. The preamble of the assessment states that ~500 data points are used for the assessment. Of these 500 data points, only one student was an "S"-type. Are the results of the survey statistically significant. How can we reason at all about Tables 5 & 6 (or others) if only one student scored as an "S" type???????

Table 7 contains composite averaged scores and percentiles taken from the lowest rows of Tables 4-6. In addition it also has the course grade percentiles for the students who have the different MBTI letters.

Table 7 – Composite Averaged Results

	Avg. SCORE	Percentiles							
		E	I	N	S	F	T	J	P
1- General questions	3.0	52	46	54	43	40	54	53	33
2- PG-Sim questions	3.4	50	48	51	49	43	56	51	46
3- Vis-MoM questions	2.7	58	44	61	12	60	46	46	70
4- Overall Average	3.0	53	46	56	35	48	52	50	49
5- Grade percentile		56	38	56	41	50	50	50	50

Table 7 provides valuable insight into the question of whether the course content teaches across the spectrum of learning styles (as measured by varying MBTI types) [18-19]. If there are significant differences between aggregate percentile rankings of different MBTI types, this would indicate that certain MBTI types are being given preference. As shown in Table 7, other than the S-types, the Overall Averages are very close across the different MBTI types. As mentioned previously, the S-types data is thrown off by the fact that only one S-type student took the Vis-MoM survey. Therefore, overall it appears that the course content does not favor one particular MBTI type over another. The last row of the Table 7 (grade percentiles) presents some concern however. Note that the E-types received overall final course grades in the 56^{th} percentile while I-Types received grades in the 38^{th} percentile. A similar difference exists between the N-types and the S-types. While these differences might simply be due to individual student aptitude or effort, it is also possible that the course content and delivery favors the extroverts (E-types) and intuitors (N-types). It would be of great help to know the incoming GPA of the different MBTI types. This could shed light significant light on the grade issue identified above. Unfortunately, these data are not available for this study, but should be pursued for future studies.

4.0 CONCLUSIONS AND FUTURE WORK

Classical engineering course content is changing from lecture and textbook styles to methods that emphasize active learning and hands-on experiences. The objective of such change is to fundamentally affect and improve the student's ability to learn, comprehend, and understand fundamental concepts. An equally weighted objective is to increase a students' interest in their course of study and to create a framework for lifelong or self-learning.

This paper focuses on the active learning methods for a particular type of course, i.e., machine design. To address our global objectives, four underlying goals are targeted: develop suitable hands-on and systems activities, create team- and project-oriented components, develop and infuse multimedia content, and assess the active learning aids according to student learning styles.

Examples for each of first three goals are discussed. The concentration is then applied to the fourth goal of assessing our active learning approach to machine design. Assessment results range from questions on particular active learning aids to more general pedagogical issues. The results of the assessment, as reported through statistical averages and MBTI type percentiles, are dramatic, insightful, and conclusive. Students, in general, prefer active learning methods. There are certain learning styles, however, that must be targeted and monitored to assure that their interest and preferences are being met. Through a balanced approach, students will have increased interest and motivation, improved recall of previous course material, and more in-depth understanding of a course's fundamentals.

While this paper sets a foundation and roadmap for assessing active learning methods, future work is needed in a number of areas. The MBTI type analysis carried out in this paper is just a start. Combinations of MBTI types (as opposed to individual letter assessment) are needed as part of the assessment. Supporting data, such as entering GPA, would also be helpful. Future research and publications will report findings in these areas.

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