AC 2007-1236: DO THEY LIKE WHAT THEY LEARN, DO THEY LEARN WHAT THEY LIKE – AND WHAT DO WE DO ABOUT IT?

Beverly Jaeger, Northeastern University

Beverly Jaeger, Sue Freeman, and Rich Whalen are members of Northeastern University's Gateway Team, a selected group of faculty expressly devoted to the first-year Engineering Program at Northeastern University. The focus of this team is on providing a consistent, comprehensive, and constructive educational experience in engineering that endorses the student-centered and professionally-oriented mission of Northeastern University.

Susan Freeman, Northeastern University

Richard Whalen, Northeastern University

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Abstract

Continuous updates to first-year engineering curricula have seen the development and implementation of a variety of new learning strategies as standard educational practices[1]. Trends involving learning methods such as active learning, case-based learning, service learning, problem-based learning, and other teaching innovations have received positive reviews, in part for their effectiveness and the ability of each to engage college students beyond the traditional lecture format. While novelty, variety, and student engagement have their merits in terms of raising interest levels and perhaps retention, continued judicious and measured application of these diverse educational methods is required to ensure that the learning objectives are being met as well. Furthermore, both professional faculty development and course development necessarily include assessment on many levels; accepting that a learning activity has the potential to teach concepts does not guarantee that it will educate students in the most effective way. Previous research by the authors provided evidence of the effectiveness of incorporating diverse active learning modes[2] As a follow up, we have sought to evaluate this variety of learning modes from our students' perspectives by surveying this population on the learning potential of each mode – or method of presenting material– and on the degree to which each course component or activity is interesting or engaging. Using a rating system, students responded for themselves by providing their ratings on learning and engagement levels for each listed class component. Correlative results showed that the students possessed a relatively distinctive profile in their 'like-learn' responses. The paper discusses this outcome and also provides suggestions on how to better calibrate our assessments with the students' perceptions. We also describe strategies to manage any mismatches that may exist between students and instructors on some of the components. The objective is to identify and combine the most effective blend of learning modes in an introductory engineering design class. Each of the learning modes and activities were described in a previous paper by the authors along with an assessment of related learning[2]. This work provides examples of evaluating individual course components, identifies characteristics of some of the ostensibly successful learning modes, and proposes solutions to components and modes presently not hitting the mark. The hope is that other educators may identify with these learning-engagement patterns in their own courses and find opportunities to make considered adjustments in the interests of their course content and their population of learners.

Introduction

Having passed through multiple evaluations and iterations of our first-year engineering courses at Northeastern University (NU), it was time for more concentrated reflection on the new educational landscape we had created. As educators in general, we have worked to make the classroom more than a "square" by venturing outside its traditional boundaries in order to become more effective and to retain students in our discipline on a genuine level. In making these incremental –and occasionally radical– adjustments in our course formats, it is also essential to continually evaluate the suitability of each of the activities and components of our courses in terms of learning effectiveness and the level of interest and engagement on the part of the students; this is to ensure that the modifications that have been made are worthwhile. We also need to consider that just because we as educators *believe* the students like a class activity does not mean they actually *do* like it. Also, because an activity may be regarded as entertaining, this does not guarantee students learn from it –or that they learn from it in the most effective way.

The first priority to be addressed in our assessment is the common denominator seen in all of the categories of strategies listed in the abstract above: *learning*. The second objective is to capture and maintain the students' interest and attention in engineering[2,3]. While we are assessing whether we as educators are attaining these primary objectives, the critical subtext of this work is to delve a little deeper to determine how tuned in we are to our students' perceptions of attaining them. Then we can to decide how to manage that information in the interests of engineering education. Restated: we tend to presume that if students like the way they are taught then they will perceive that they have learned the subject at hand and conversely, a lack of entertainment may result in the impression of reduced learning, but is this really the case? Also, we may think we understand the students' perceptions of learning and interest, but we know from experience that this is not always true. We can begin to address these issues by breaking down all elements of the course for measured analysis.

If we look at our collective goals as engineering educators, typically they are to:

1. Facilitate student learning and concomitant motivation.
2. Strengthen genuine retention of students.
3. Prepare students for engineering application in the industry outside the classroom.
4. Identify the most effective selection of course components and best use of class time.

While each of these objectives might be considered mutually exclusive on some levels, an ideal course would be one developed to create maximum overlap across each of these goal categories. Ensuring that students like their work certainly helps to retain them, but do they feel they are learning from the same experience?

Review of Literature

Learning Styles. It is well established that using a variety of teaching styles in our classrooms increases the chances of our students retaining and enjoying what is taught[4, 5]. Understanding learning styles is a key component of how students learn, and teaching styles –which adapt to those learning styles or not– are the means for the instructors to both affect and effect learning. One well-established schema proposes four dimensions or categories of learners which are presented in Table 1[6]: (1) *sensing* (concrete, practical, oriented to facts) versus *intuitive* learners (conceptual, innovative, oriented to theory); (2) *visual* (pictures, diagrams, images) versus *verbal* learners (written and spoken); (3) *active* (tries things out, works with others) versus *reflective* learners (learns by thinking through, works alone); and (4) *sequential* (linear, orderly, learns in steps) versus *global* learners (holistic, systems thinkers, learn in large leaps). Difficulties occur because traditional lecture-style teaching is done by professors who tend to be primarily intuitors, resulting in classes that are verbal and passive. Most students are sensors, visual learners, and active learners. Both the majority of students and teachers are often sequential, but this leaves out the subset of students who happen to be global learners. Due to this disparity, active learning approaches that apply a variety of teaching experiences to engage all kinds of learning styles have been developed and used successfully in classrooms because they cross-match more categories of learners. Teaching styles and learning modes used to overcome the learning-style mismatch include active learning, collaborative and cooperative learning, and problem- or project-based learning[7,1].

Table 1. Dimensions of Learning Styles[6] (Felder & Brent, 2004)

Dimension	Types of Learners within each Dimension	
Perception	Sensing/Sensors	Intuitive/Intuitors
Input Modality	Visual(s)	Verbal(s)
Processing	Active(s)	Reflective(s)
Understanding	Sequential(s)	Global(s)

There are methods for determining the preferred learning styles of students. Some researchers have developed basic questions to be considered at the beginning of the term to help assess the class[8]. There are also more formal instruments such as the Kolb Learning Style Inventory[9]. These assessments help the instructor design curricula and activities, but also aid the students by providing information to help them adjust when their learning style does not match the teaching style. From this, a positive sense of empowerment can result. The students can capitalize on what they do best, and learn to compensate when there are difficulties with mismatches in styles.

Tileston, while drawing conclusions similar to other established models, describes a simpler model of learning styles by presenting three modalities[10]. The modalities are auditory (learn by hearing), visual (learn from a mental model that can be seen), and kinesthetic (learn through movement and touching). Lecture favors auditory learners, but even this group loses interest after about 15 minutes. Tileston suggests teaching activities from all three modalities, and having new information given in 15- to 20-minute segments (college age and above, less for younger students) to enhance learning.

In Silberman's text on Active Learning[11], he starts out by reinforcing the notion of learning styles with some research on student preferences for learning modes. He has assembled data from 15 years of having instructors use the Myers-Briggs Type Indicator on incoming college students. These results show that 60% of the students have a practical rather than theoretical orientation toward learning, and that this percentage is growing. Other research has shown that students prefer concrete active learning activities to abstract reflective learning by a ratio of 5 to 1[12]. The general conclusion is that active modes of teaching and learning create the best match for today's students. These can include: small-group discussions and projects, in-class presentations and debates, experiential exercises, field experiences, simulations, and case studies. Silberman also discusses the social side of learning, "[Students] tend to become more engaged in learning because they are doing it with their peers. Once involved, they also have a need to talk about what they are experiencing with others, which leads to further connections." This can only happen with active learning and collaborative learning activities[11]. Do these benefits mean that other types of learning need to be diminished or removed from the course structure, or is there a combination that might benefit everyone? This is the question we were hoping our research would shed light on.

Motivation and Higher Learning. The previous discussion on learning styles and active learning and the importance of understanding each in the design of in-class activities, course experiences, and homework cannot be understated. As educators we should be striving to develop activities to empower students to think at a higher level. Much of what is done in a traditional lecture is considered passive and material is presented in a linear fashion. This tends to cultivate the students' ability –and thus inclination– to follow a recipe approach to solving problems. It is well known that the use of active and problem-based learning inspires students to think on a higher, more multi-dimensional level. In addition, it provides students the opportunity to learn in teams, innovate with hands-on activities, foster relationships, and discover what engineering is really about –which is clearly quite different from what students could discover if they only experienced a traditional lecture-based course. In order to be successful in attaining our learning objectives we must ensure 'constructive alignment' that is, we must design or construct course elements with adequate explanation and assessment while also trying to make sure students are motivated and have obtained the required perquisite knowledge[13]. Seery *et al.*[14] related the work of constructive alignment by Biggs[13], Ramsden[15], and Prosser[16] to develop a deep learning paradigm –that which fosters a deeper learning experience for students– with the following eight points:

1. An interest in background knowledge is important, as a lack of interest can discourage deep learning.
2. Clear statement of objectives and quality feedback encourages deep learning.
3. The design of assessment methods should emphasize conceptual understanding.
4. Pedagogical approaches must foster active and long-term learning.
5. Choice in content and method is also beneficial for the deep learner.
6. Apathetic or inconsiderate teaching discourages deep learning and is more suited to developing a surface approach.
7. An excessive workload will only serve to encourage surface learning even for deep students.
8. Previous educational experience that discourages deep learning will further discourage a deep approach.

With an appreciation of these points on learning and motivation and an understanding of the student learning style demographics, we are able to move toward making the necessary adjustments in each course component to improve learning effectiveness, student interest, and engagement. After all, it is our desire as educators to have students leave our courses with not only an understanding of course content and a range of learning skills, but also the ability to be metacognitive about learning and have the motivation and desire to continue learning[17]. This not only provides for a positive experience for students and educators but also has the societal benefits of improved retention in engineering, and with those increased numbers, more engineers who are better equipped to develop and apply solutions in the world around them.

Learning Styles and Learning Activities

Previous work by the authors describe most of the following learning activities in greater detail and how each were infused into a first-year Introduction to Engineering Design course[2,18,19]. What follows is a brief summary of each learning mode that was surveyed and how it is related to the learning styles as described by Felder and Brent[6].

Engineering by Design Textbook. The textbook used is very similar to many other introduction to engineering and design textbooks currently available. The text is developed around the six phases of the design process outlined by Voland[20] as: Needs Assessment, Problem Formulation, Abstraction and Synthesis, Analysis of Alternatives, Implementation and Reflection. The book uses many case studies to emphasize the engineering principles discussed in each chapter. In the course, students read and complete selected homework assignments from each chapter. The textbook clearly benefits the verbal, intuitive and reflective learners.

Preparing & Presenting Case Studies / Watching Case Study Presentations. In these exercises, student teams are formed by interest and each team is given an historical topic or case study from the textbook to research and present. The presentation should contain a summary of the case, identification of the important lesson(s) learned concerning engineering design, and a similar example in which comparable principles are illustrated. This exercise reaches multiple learning styles: the sensor since it is oriented to fact, verbal because of the written and spoken words, active because of the teaming, and sequential because of the natural order of the process.

Minor Design Project: Planning & Building / Preparing Demo & Demonstrating. This first project is assigned early in the course to individual students or small teams. The same task is given to the entire class. They are to build and demonstrate a device of their own design. They experience the design process hands-on with a strong emphasis on the design steps of problem formulation, abstraction and synthesis, and implementation, with some iteration. There are multiple demonstration days, during which the students review others' projects and show the results of their own work. Some examples are: a pumpkin drop, ping pong ball launchers, mousetrap cars, and devices to wake up a roommate[2,18]. The opportunity is present for all learning styles to be reached. Sensors will benefit from seeing the physical fruits of their labor while intuitors are able to apply concepts, perform calculations, and innovate. Visuals are able to draw and diagram whereas verbals and reflectors benefit from research and book reading. Active learners get to work in teams and have a hands-on approach to the solution, while sequentials and globals are both covered through the nature of the design process and iteration.

Professor's Presentations & Explanations. This learning mode includes any material presented in the form of a lecture, PowerPoint presentation, written words, diagrams, or formulae on the board or on transparencies. This includes material presented and discussed with the professor who is moderating the class discussion. Students typically are required to take notes or download presentation summaries from the internet. Lecture formats will mainly benefit the verbal passive learner and perhaps the sequential learner.

Movie Analysis: Doing & Presenting / Viewing Presentations. In this assignment, teams of three or four students select and analyze a scene from a movie. They are answering questions such as "What engineering principle was captured, applied, or represented, and was it correctly portrayed?". A report on the engineering principle(s) must be accompanied by numerical analyses. Student teams give a short overview to the class, showing their selected scene and related findings. This is another opportunity to have them research scientific principles, become dynamically engaged in public speaking, and practice organizing an effective visual presentation. This is also an additional example of an exercise that reaches multiple styles of learning. The styles used are: the sensors since it is oriented to fact, intuitors because of the theory involved, verbals and visuals because of the written and spoken words, and diagrams or pictures used, actives because of the teaming and sequentials because of the systematic order of the analytical process.

In-Class Exam Review Activities. Instructors use various methods to help students organize notes and reflect on past lessons learned in order to prepare for exams. This may include handing out review sheets, having students work on fill-in or matching exercises, class discussions on important topics, and using other media to outline possible areas of assessment. The largest benefit would be realized by the verbal learner.

Directed Research Activities: (Internet, Patent Search, Site Visits, Interviews, etc.). These activities involve research on case studies, or relate to the Major Design project (described below) and the problem formulation and analysis phase of the design process. Students must conduct an extensive literature and patent search relating to their design project topic. Other means of gathering information that is relevant to the project may include a site visit, conducting interviews with engineers, or creating and executing a marketing survey. Students are required to organize and present this information in both a report and presentation at the end of the term. In much the same way as many of the other activities, this project will reach multiple learning styles depending upon which aspect of the project is being performed. Verbal learners will do well with the written information and intuitive learners will be challenged with interpretations of concepts, calculations, and theory.

Design Deconstruction & Presenting Poster / Viewing & Evaluating Posters. Student design teams deconstruct (reverse engineer) a product or device to understand how the design process was used, then prepare a poster presentation to be viewed by all first-year students. This course element has been added to: (1) emphasize the details of production and manufacturing in product development, (2) demonstrate and capitalize on the effectiveness of using a poster session as a method for disseminating a large amount of information in a short period of time to a large population, and (3) provide students with the opportunity to see what other colleagues have been doing. In addition, students are required to evaluate and comment on the posters in order to determine the "best" posters. Here the sensors, visuals, actives, and sequentials alike can do well with the concrete aspect of the diagrams or pictures involved, teaming, and the deconstruction sequencing seen on the poster boards. Also an intuitive will benefit because of the theory involved; verbal and reflective learners will do well with the written report.

Teamwork/Team-Building Activities: (Tower of Straws, Goals Consulting, etc.). Activities such as Tower of Straws and Goals Consulting can be used as teambuilding exercises that demonstrate various phases of the design process through cooperative group exercises. For example, in the Tower of Straws exercise the instructor divides the class into groups of 4-6 students. Each group is given 25 straws, a pile of paper clips and a small wad of modeling clay. The instructions are to build the tallest structure in 20 minutes using the materials provided. Some additional criteria used as goals are most: creative, earthquake resistant, hurricane resistant, and aesthetically pleasing. The class discusses the comparison to a real-world scenario in which they would have resource and time constraints, and must work as a team. This activity covers all design phases in an abbreviated manner: needs assessment, problem formulation (setting goals), synthesis, analysis, and implementation[21]. Additionally, once the towers have been built and evaluated, there is also reflection on how the task and approach may have been revised, benefiting the reflective learning type. In many instances there is opportunity to try things out, or to deduce, both of which will benefit the active and intuitive learner.

Major Design Project: The Process / Preparing Presentation & Final Design. This is assigned immediately after the Minor Design project has been completed and requires more thorough exploration of each engineering design step. It is coordinated with a more advanced and in-depth presentation of each design phase outlined in the textbook and in class. The course requires students to select and develop projects that are humanitarian and service-based in nature. Students compile a number of intermediate assignments to create a final design report then present their findings in an end-of-the-term design presentation to the class. Students are given the opportunity to role-play investing in each others' design as well as to rate one anothers' presentations for design creativity, organization, and practicality. As with the Minor Design project, there are opportunities for all learning styles to be addressed. Sensors will benefit from seeing the results of their work, while intuitors are able to apply concepts, perform calculations, and innovate. Visuals are able to draw, diagram, and prototype, whereas verbal and reflector types benefit from research and resource reading. Active learners get to work in teams and have a hands-on approach to the solution, and finally, sequentials and globals are both covered through the structure of the design process and iteration.

In-Class Practice ➔ Present Findings (Problem Formulation, Goals Consulting, Abstraction & Synthesis, etc.). Many of these activities are adopted to emphasize the day's lecture topic. Most use only 15 to 20 minutes of class time and are used throughout the course to relate to each design phase discussed in the textbook section above. Activities include using problem formulation techniques such as Duncker Diagrams, Kepner-Tregoe Problem Analysis, Kepner-Tregoe Situation Analysis, and Statement-Restatement Technique on current events. Numerous creativity stimulation techniques are used like brainstorming, bionics, checklisting, synectics, analogies, adaptation, fresh perspective, inversion, brainwriting, morphological charts, and idea diagrams. Others include techniques on Decision Analysis, for example using the Kepner-Tregoe Decision Analysis or Rank-Order Matrix to select an appropriate solution to a problem. In the Goals Consulting session, design teams role-play as clients and consultants for their Major Design Projects. The consultants outline a list of goals they perceive from the client team plus suggestions for possible relevant background knowledge. The consultant team's suggestions are compared to those of the client team and as a result, new ideas and viewpoints emerge. As with the previous list of in-class activities, each of these by design have a reflective component which will benefit the reflective learner. The active learner will benefit from the hands-on elements and teamwork, while the intuitive learner will have the opportunity to try concepts. The sequential learner can follow a logical progression to form a conclusion.

Displaying Examples & Samples of Other Students' Work. Instructors may decide to show examples of past work to help current students understand what is expected of them in order to achieve the highest standard. This will include samples of both recommended and less-preferred ways to approach the management of material. It is used prior to assignments being due and as reflection of previously submitted work. This is most suited for the verbal and reflective learner, but any student who learns by example can benefit from seeing models.

Guest Speaker from Industry: Reebok®, Philips®, etc. Students are exposed to various speakers from industry to provide fresh perspectives on engineering topics discussed in the classroom. Speakers typically bring in a product and demonstrate its functionality while taking the students through the design process. As with a traditional lecture-based course, the verbal learner will benefit the most but sensors will appreciate handling the physical models while sequential learners can more easily follow a product's process from prototype to market once real-world context is provided by the visiting subject matter expert.

Movies/Videos selected by the Professor. Here students view films on selected engineering topics. For instance, a film on the Wright Brothers' Flyer introduces the students to the design process. The Nova special, "Battle of the X-Planes", looks at two companies trying to meet the same design goals from two very different approaches and emphasizes the importance of proper analysis and dealing with design tradeoffs. Another is a film which presents engineering disasters that often have resulted in the loss of life and property and diminished engineering credibility. Homework associated with each varies from answering questions about the topic to in-depth analysis and class presentations. For example, in the disasters movie each Major Design Project team is assigned one of the disasters to further research the technical and ethical issues that were involved. This exercise brings ethics and product liability into their analyses and provides each Major Design team the opportunity to present together for the first time before having to present their final design projects at the end of the term. Movies help both the visual and verbal learners through pictures and diagrams as well as the spoken word, respectively. In addition, active learners will benefit from the teamwork and reflectors from composing the reports.

One-Minute Engineers: Preparing / Viewing. This activity gets the students involved in their own learning by having them explore their surroundings and find an engineering topic to present to the class[19]. Each student has approximately one minute to start the design class each day with a presentation on a device, a person, a concept, a vocabulary term, or an historical or current event related to engineering. This exercise will benefit the verbal learner but also allows for self-directed study which will benefit the reflective learner. Since visuals and physical models have been recommended –and are now required– a higher percentage of sensors and visual learners can be accommodated with this format.

Infusing and Assessing Multiple Learning Modes

As noted in an earlier publication, a wide variety of learning modes and activities were infused into an introductory engineering design course over a period of several years[2]. Comparative results between the activity-based versus lecture-based courses revealed significantly positive outcomes in the areas of (a) overall instructor effectiveness, (b) amount learned, and (c) overall course effectiveness in favor of those sections containing a higher variety of learning modes. Assessment of learning for the design course was documented in that recent publication.

To further evaluate the macro-level outcome of the previous research, we felt it would be valuable to "walk in their shoes" to obtain feedback from students' perspectives on a decidedly more micro level. To review our strategies, additional evaluation methods were undertaken in this follow-on work. As a continuation of assessing the overall course sections, we collected data on two aspects of *each* of the components of the course described above: (a) learning value, and (b) interest and engagement level. As educators, we review these outcomes to better ascertain whether the elements of our first-year design course offers the opportunity to learn that we have envisioned for it.

Methods

While Engineering Design sections are taught by individual instructors, the course is conducted with a team-planning approach. It is coordinated by 2 of the 3 authors in any given semester with team meetings for all instructors every 2 weeks throughout the semester. Instructors of this course conduct most of the learning modes in a similar fashion. A dual-component survey was administered to 9 sections of the student population in engineering design classes (N= 232). The survey was administered in class during the last week of the semester. The rating section used a 5-point Likert Scale and students were asked to rate various activities on the degree to which they helped them learn and how engaging or interesting they were. Not all of the activities were used by each Professor, in which case students were instructed to place a 'n/a'.

The instructions, format, and ratings are shown on the questionnaire page in Appendix A. After the ratings for each of the learning modes, requests for 3 open-ended commentaries were posed on the reverse side of the survey:

Comments on what is <u>not</u> effective in your learning process:
Comments on what <u>works well</u> for you in learning about and applying engineering methods:
<u>Suggestions</u> for improving learning methods and/or <u>ideas</u> for other class-related activities:

Results and Discussion

Correlation of Education vs. Engagement: The Learn / Like Outcomes. To determine if there may be any significant statistical correlation in the learning vs. engagement dimensions, a Pearson Product Moment correlation test was conducted on the data for each learning mode. For the 22 items listed, the aggregate correlation coefficient for the Learn (X) versus Like(Y) was 0.748, a relatively strong–but not linear– relationship between the two educational dimensions.

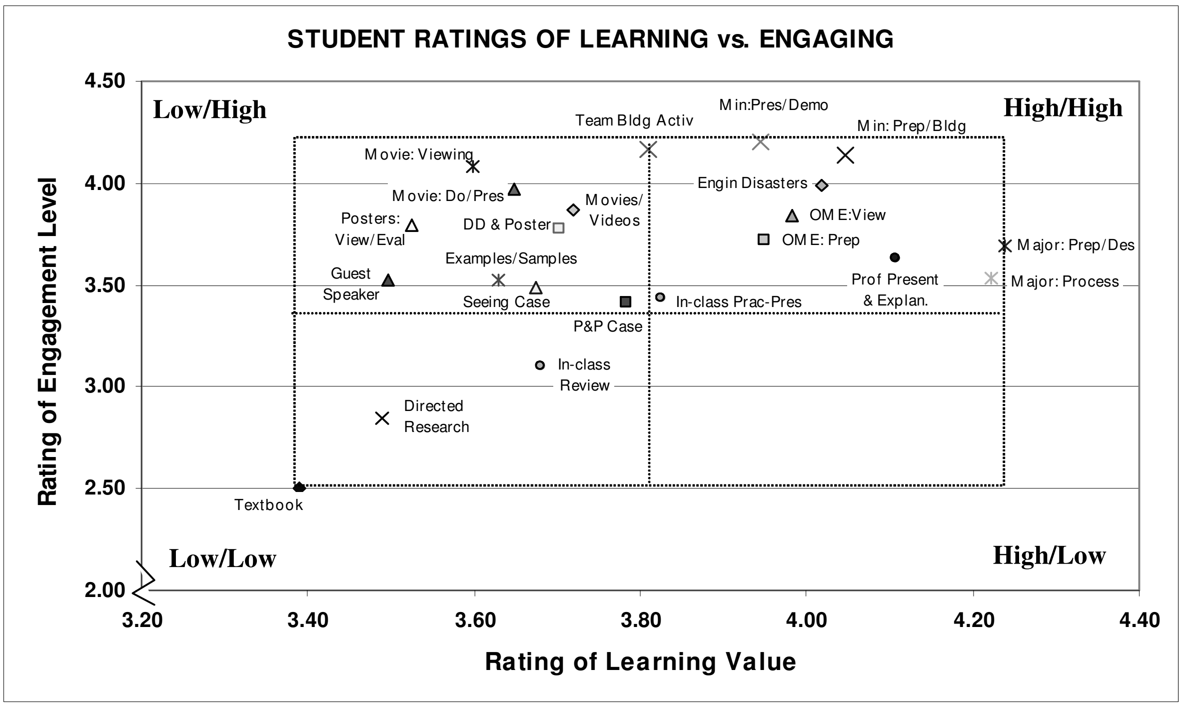

Figure 1. Results of the Learn/Like Survey showing learning/engagement ratings for 22 learning modes.

The plotted results of the Like/Learn survey are shown in Figure 1. The graph is divided into 4 quadrants generated by incorporating each of the extremes into an enclosing rectangle, which is bisected in both directions for reference. Results discussions will refer to Learn/Like pairings, respectively, with terms such as *High/High* for those activities that are perceived to be simultaneously most effective for learning and highly engaging, found in the upper right quadrant. *High/Low* would refer to a course component which the students attested was good for learning, but not very enjoyable or engaging. In terms of taxonomy, the remaining quadrants are *Low/High* and *Low/Low*, also referring to the corresponding Learn/Like scores and their relative locations in the quadrants.

The following discussion reviews the results and embarks on an analytical quest to determine how we may apply our findings. Although we might be tempted or even feel compelled to change our courses to suit the students' opinions, we also need to balance the their judgments with our own objectives and experience with students. Most of the focus for change or discussion is on possible courses of action in the case of discrepancies. These areas prompt the most reflection and catalyze the search for possible improvements.

High Learn / High Engagement Quadrant. Both activities associated with the Minor Design Project are in the upper right corner of the chart, the zone of high learning and high engagement. These are the *Minor Project Preparation & Building* along with the *Minor Project Design & Presentation*. All first-year engineering students participate virtually simultaneously on their various design-and-build projects. As many of these students live in the residence halls on engineering floors, the projects create an additional "buzz" as they compare and compete for brainstorming and construction superiority. The engagement level for the students for the activities in this project is understandably high because the final products are creative, physical, and visual. What is also apparent from the duality of the high rating is that they also perceive that much is learned from this project. This may reflect the fact that in subsequent classes during the term, all instructors frequently refer back to this project. This allows the students reflection in both writing the paper and seeing others' successes and failures. They are also then able to consider their own work, in comparison to others and with increased theoretical knowledge, after the initial rush of the construction has subsided. As discussed previously, the opportunity is present to engage all other learning styles with this project, which means we would expect this project to be popular with a majority of students since they have essentially all been addressed.

Another High/High cluster is *Viewing & Discussing Engineering Disasters* movie clips in class. In addition to viewing movies, which is, –of itself– popular, the students get involved by working in teams and doing their own research. Tying this learning mode to ethics and the need for technical knowledge seems to make the topic resonate even more. Again, what makes this more universally successful is the exercise's ability to address multiple learning styles and therefore more students, and its ability to be both entertaining and educational.

The activities associated with the *One-Minute Engineer* (OME) also are found in the High/High quadrant, both in terms of *Preparing & Presenting* and *Viewing Others' Presentations*. As noted, this activity is conducted at the beginning of almost every class, and contains current engineering events. This leads us to hypothesize that its recurring nature gives it a perception of being important, while its relevance to everyday events makes it personally significant to the students. Both of these factors may contribute to its perceived value to the students. Anecdotally, when there has been a day without an OME after many weeks of regular OMEs, students express visible and vocal disappointment about its absence.

Also with relatively High/High ratings are *Professor's Presentations & Explanations*. There was some amount of surprise at this finding, because part of the premise for developing active learning activities is that lectures alone are not sufficiently engaging. The explanation for this apparent anomaly may lie in the fact that the subject presentations are deliberately accompanied by active learning for the most part. This further fuels the notion that the students are attracted to and respond positively to a definitive mixture of entertainment and education. The rating indicates that by combining the two learning styles, we as educators are ostensibly creating a win/win situation; the activity is perceived to have more value because of its association with the lecture, and the lecture becomes more engaging –and relevant– through its association with other activities. The high rating in both dimensions leads us to conclude that the students *do* value the content and relevant presentations that are connected to the activities. By their own admission, they want the “meat” of the course. Given that other content-rich activities, such as reading the textbook, did not fare so well (discussion to follow), we now know we must concentrate on how we combine, introduce, present, and reflect on each of the learning modes that we adopt.

Low Learn / High Engagement Quadrant. There are a few learning modes that our student population regard as very interesting and engaging, but which they also concede that they see little learning potential in them. Examples are *Viewing Others’ Movie Analyses* and *Viewing Other Teams’ Design Deconstruction Projects*. In general, while these are reportedly enjoyable to the students, they are not perceived to be as educational as we would like for the investment of planning and class time. A possible reason for this is that most students correctly believe they will retain and learn more by doing the activity themselves as opposed to observing the results of others –by doing, the lesson is learned and retained. The rating shows that this divergence from the optimum learning opportunity is noted by the students and impacts on their assessment of the course.

At the moment the above Low/Low activities have been identified as being inefficient for meeting the learning objectives of the course. As educators, we can now try to capitalize on the known capability of these activities to harness the students’ attention and energy. At the same time, we must also work on embedding more deliverable lessons and applications into the experiences to make them perceived to be more effective and valuable by the students.

High Learn / Low Engagement Quadrant. Which of our learning modes/activities do the students find to be unengaging, but highly valuable for learning? None! Apparently, if there is not a sufficient level of personal engagement, there is also very little perceived potential for learning. This leads us to theorize that the inverse may also apply, in that if learners find a topic educational, interesting, and/or valuable on the face of it, they would consequently regard it as to some degree personally engaging and rewarding.

These findings are also very interesting and encouraging because they do not suggest if students are having fun they *do* automatically think they are learning. These results also counteract the notion that having fun is *necessarily* an antecedent to learning. The students’ previous responses for the Low/High quadrant attest to their discernment on both sides of this matter.

Low Learn / Low Engagement Quadrant. The Low/Low cluster of learning modes is shown in Figure 2. The three modes to consider are the *Textbook*, *Directed Research* and *In-Class Review* as they presented with low combined scores. What do we do with the Low/Low modes? The options are (1) eliminate the activity, (2) change nothing (3) alter the activity, or (4) present or package the activity differently. These options will be discussed for each learning mode listed.

Textbook is found at the lowest extremes on both continua. However, at 3.4/5 in learning and 2.5/5 in engagement, it is not severely low. The textbook is referenced, reviewed, and used in activities, but fundamentally –and not surprisingly– the students rated it low, just as they do in end-of-course evaluations. Although the textbook scores at the lower end, eliminating it is not an option as it has been agreed by the team of faculty that the textbook is of fine quality and contains necessary content and reference material for the course. One option that may be possible would be to utilize an online text, which can be customized and aligned to fit the course's learning objectives more closely. Another possible change is to work more from the text, referring to its sections even more frequently and more deliberately than we currently do. Written commentary from the students supported this as some indicated that they did not see the point in purchasing the text book because they perceived it to be largely unused. In addition, mapping some of the High/High activities to the *Textbook* directly and immediately may increase its perceived value to the students, having hopefully a similar effect as to what seems to have occurred with *Professor Presentations*. These latter options in effect alter the mode and repackage it to increase its perceived relevance and usefulness to the students, and with this new perception, thereby possibly increase its learning and engagement level.

Directed Research is also found to be in the Low/Low quadrant. As discussed, this involves conducting patent searches, finding material to supplement case studies, researching technical principles, and investigating product development beyond the textbook. These activities do not inherently offer the uninitiated first-year student the prospect of stimulating and imaginative engagement, and their inexperience at detailed research means its inherent worth is likely to be undetermined and undiscovered. The solution to improving the learning potential of *Directed Research* may come from presenting it differently in order to help the students see its value and thereby find it more engaging and worthwhile. As High Engagement ratings were consistently associated with activities aligned with real-world experiences and specific educational gains, *Directed Research* activities need to be more focused on these areas. This might include better training on how to perform research and how to extract and use the information obtained for project development and academic success. With a greater emphasis on its connection to and position in the engineering world, the students may learn more and find research more interesting. Also, small but frequent research activities may help it become, like OME, part of the fabric of the course, enjoyed and expected.

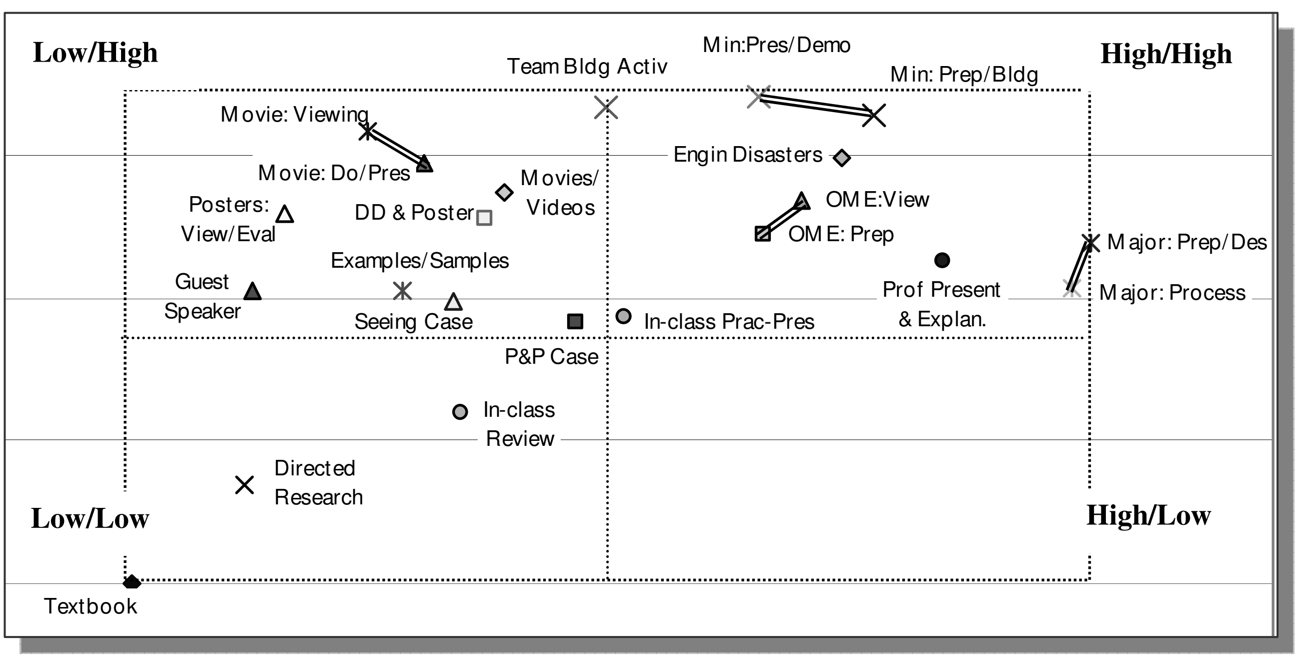

Figure 2. Close-up of Learn/Like Quadrants with activity pairs; X = Learn/Interest, Y = Like/Engagement.

Another lower learning mode is *In-Class Review*. This typically involves devoting some class time to preparing and reviewing for exams. On reflection, it is mainly the vocal students who ask for this, but this does not necessarily reflect the needs of the majority. The feedback obtained suggests the prepared and motivated students neither want nor need this review. Thus if we provide this, it is not as accommodating as we might perceive; it is helping the less-prepared minority, and is relatively ineffectual and possibly detrimental (due to frustration) for the conscientious students, which is not necessarily the desired outcome. *In-Class Review* as it stands, is a candidate for elimination. Review sheets, a small sample of candidate exam questions, a detailed course outline, or an out-of-class session, can provide the necessary guidance for exams without consuming valuable class time and might serve as an adequate substitute.

Medium Learn / High Engagement Area. The "I Saw it in the Movies" scene analysis assignment was engaging, not surprising, but lower on the learning scale than we might desire or have expected. This was true for both elements of this assignment, *Preparing & Presenting* and *Viewing Others' Presentations*. Once again, the solution seems to lie in re-marketing it so that its connection to the educational process becomes more apparent to the students. A way to effect a learning shift might be to change the presentation of the assignment to require the students to take on more of a teaching role. They would portray expert engineers, teaching the class about their topic. As a corollary to this, and perhaps providing more tangible educational value to the students, including some of the technical and specific material from the presentations on the exams might underscore the value and importance of this material.

Discussion

Alongside efforts to foster an engaging environment, one still has to be careful in gauging and managing the class and group dynamics. In some classes, there exists plenty of team camaraderie and this is generally welcomed and appreciated and is identified in the student surveys as a source of student satisfaction. Teams often present their results to the class and in most cases this type of learning is found to be engaging and even enjoyable. However, a percentage of the population does not place a high value on being taught by their peers on a regular basis. As noted in the High/High discussion on lectures, a larger-than-expected percentage of our population expects and even welcomes traditional instruction from the professor. The solution to redressing this minor imbalance lies in the educator being aware of the conflicting student needs and then determining when the lessons are best delivered by the instructor versus student teams. It is also interesting to note that while students generally like presenting, they sometimes don't like being an audience to others. One would think you couldn't have one without the other! This suggests a possible gap in some students' development of professional patience, and perhaps knowing how to be receptive to learning and being inspired by the work of others –two key professional skills. Possibly the environment and curriculum can be further developed to help the students become more open to opportunity from everything around them, it seems that some students do not grasp "what is in it for me" when watching others. It may be that it is our role to help them gain that perception and identify value for them.

As faculty we expected the *Design Deconstruction* and *Poster Session* to be higher in the learning ratings. This assessment was administered in the first year of that activity, so changes to improve this event have since been implemented. These changes included introducing the assignment earlier in the semester and generating interest with samples, examples, and publicity.

This gives the students a vision and sense of what will be seen and learned from the tasks, once again drawing a "value connection" for them. In our inaugural Design Deconstruction event, only selected sections participated. The subsequent time the event was run, the entire first-year engineering population participated in the all-day event. This provided more posters and deconstructed products for all to review making it a larger, grander –and presumably more educational event. We also enjoined the interest of the student newspaper to give it a value component outside the classroom. For the future, we plan to increase the discussion and reflection of the project and ensure that the goals are clear for the project and for the written report that follows the activity.

Activity Clusters. In reviewing Figure 2, there are also clusters of items that are related. These pairs are connected by double lines in Figure 2. That is, the two items associated with the Major Design project (*Process & Preparing, Presenting & Final Design*) are very close to one another, with learning values almost equal (difference<0.05) and difference in engagement rating less than 0.1. Similarly, with the two items for the Minor Project (*Planning & Building, Preparing Demo & Demonstrating*), the engagement ratings are very close, and learning ratings differ by less than 0.1. In addition, *One-Minute Engineer* items are also close together, as well as the *Movie Analysis* learning modes. This result is logical and not unexpected, but because they are not identical, the students are also perceptively differentiating the distinct characteristics of each mode. If they found one part unsatisfactory or not as satisfactory as the related mode, they would rate it as such. Fortunately, this result gives the impression that the students related items together but not identically and most of these tandem activities are rated in the higher quadrant areas.

Student Responses to Open-Ended Questions. A multi-pass content analysis of the open-ended responses revealed that the general sentiment of this population is reflected well in the quantitative results[22]. The comments written by the students answer the questions: "What is not effective in your personal learning process? What works well for you in learning about and applying engineering methods? and What are your suggestions for improving learning methods and/or ideas for other activities for this course?"

First, considering what works well for the students:

- *Activities & Projects*: 56.6 % of the comments pertain to major and minor projects, in-class activities, and hands-on work. They clearly find that these projects, teamwork, and building and presenting work well for their learning.
- *Lectures & Note taking*: 13.6% relate that this works well; it is the next highest, although *Activities & Projects* clearly dominates. This includes PowerPoint, visuals, examples, and demonstrations.
- *Group Work*: 9.5% of the comments find this works; both in class and on the projects.
- The other comments on which modes work well in order of highest to lowest percent are *Visuals*, *Blank* or *None*, *Presentations*, *Reading & Note-taking*, *Discussion/Interaction*, and *Case Studies*, all under 5%

The comments under what is not effective also elaborate on and primarily reinforce the quantitative results. A summary of these are:

- *Blank/None/Good as is*: 27.1% do not find anything worth commenting on that they hadn't rated already.
- *Reading & Note-taking*: 26.1% regard the textbook, reading, and related activities as not helpful. This is consistent with our results and with how they rate the textbook in the evaluations.
- *Lectures & Note-taking*: 18.5% report this does not work well, with most of those about lecture *alone*. As seen in the detailed comments, what works well for some, is not effective for others.
- Most of the remaining categories are fairly close and all are less than 8%; named among them are *Case Studies, Visuals, Presentations, Activities & Interactive Work*. It is important to note that in some of these categories, such as *Activities & Projects*, many of the comments say not enough hands-on projects, or that they like them but there are too many due simultaneously, so this is not inconsistent with the previous results. Further, as detailed above, although v*isuals* are generally preferred, it is also possible to overuse them; in particular, overuse of PowerPoint drew some comment.

In the third question, there were many suggestions offered, but most of them relate to the items that were initially set out on the rating sheet and are not new ideas. A summary of these shows:

- 40.2% are *Blank/None/Good as is*.
- *Activities & Projects*: 35.9% are related again to this category, with most saying keep them or do more projects and active items. Only 1 single comment requested fewer projects.
- *Group Work*: 5.8% mention group work, such as more group work, more in-class groups, and some on providing more guidance.
- *Lectures & Note-taking* and *Reading & Note-taking*: Both of these are close to 3.5%. Some examples are less reading, less or no textbook, fewer slides. There were also a few comments that wanted to use the textbook *more* as noted above.

The Suggestion Hall of Fame

From the suggestions, there were a few notable new ideas. A recommendation worth considering is to use products and improve them, which was also a suggestion from One-Minute Engineering analyses. This aligns well with the objectives of the course and will be explored for the future. Many comments mention concern with simultaneous projects and assignments. This is something to keep in mind, but it also provides an opportunity for two principles to be conveyed: (1) certain projects and assignments lend themselves to longer lead times and it is a service to the students to provide this advance notice, while others are more suited to a quicker turn-around time, and (2) these overlapping activities provide opportunity to practice good time management. These factors can also be related to the real world in which simultaneous projects with deadlines are the usual *modus operandi*, and this is good practice and preparation. It is our mission as educators to guide the students in understanding these objectives. Thus while the time frames may not be changed, the importance of their presence in the curriculum can be better outlined, hopefully thereby reducing the student frustration levels.

Numerical Effects

Also important to note is that in relation to many of the learning modes, there are numerous comments and ratings on both sides of an issue and at both ends of the scale. For example, there are nearly the same number of comments reporting that case studies work well for their learning as those that find them to be ineffective. This is true for some of the smaller-sized categories. However, for the *Activities & Projects*, they are almost all in the same direction, positive, and for *Textbook* reading, more predominantly on the negative side than the positive. There is enough population divergence on these for us to make note of the split pattern. It is reminiscent of the end-of-course evaluations, in which out of 30 students, 2 love the course, 2 hate it, and the rest found it to be pretty good. This reminds us once again that just because something may be said loudly or passionately does not mean it represents a common view and it further emphasizes the need for this type of ongoing assessment to filter better the requests made and enable a more objective perspective to be viewed.

Finally, while the result of this research initiative is a correlative scatter plot, our focus is not to presume to determine which of the axes represents the dependent variable, or whether there is one for that matter. Intentionally, this issue is not part of our hypothesis. We cannot test for this, our claim being that the two factors of engagement and learning are undeniably intertwined; there is not a singular causative flow for the two dimensions of learning versus engagement. As such, we are analyzing relative locations of the various learning modes to ascertain which of them we should remove, change, reconsider, review, or reinforce.

Reflections and Recommendations

This study is invaluable for building on and developing existing successful areas and for implementing and perpetuating effective features of learning modes as appropriate. We plan to keep what is working, the *Minor Design Project* for instance, and tweak some of its associated activities. For example, although OME has already been adopted by several professors, to inspire more interest we can now further emphasize its value to the students and the ease of adoption for the professors teaching the course by reference to this study.

As discussed above, it is interesting to note that there are no High Learn/Low Engagement modes in the lower right quadrant. Although everything in the course is not rated as highly engaging, the students perceive themselves to be learning through a variety of different assignments and modes, and it may be that it is this variety that keeps the overall engagement factor higher. As we know from analysis of learning styles, addressing all the different styles is essential. From this we can extrapolate that course content ought to include some lectures, –even textbook reading– and the students themselves attest that they don't always need to be building a tower to learn. Apparently some activities that have high learning characteristics are not required to have high engagement ratings to be acceptable to the students. It is a balance, achieved by variety with emphasis on *what* the students learn, counterbalanced by *how* they learn it. While some of these areas are hard to pinpoint precisely, what did hold to be true from our research was that the amount of perceivable value to the student impacted on the activity's learning and engagement rating. Thus it became evident that possible solutions to improve student course satisfaction lie in first specifically identifying the value, or lack thereof, in the activity for the student.

In reviewing the matching profiles of Learn/Like we have tried to understand and focus on which components or characteristics created these perceptions for the students. What do we change? Even activities that were not rated as favorably with the students are part of the course to meet specific learning objectives. Since we as professors believe these activities should be retained in the course regardless of what the students convey, what then are our options? To review:

1. Retain them and change nothing.
2. Eliminate them or remove parts of them.
3. Clarify objectives to the students for using them.
4. Revise them after careful review to enhance their potential for learning and engagement.

High/High clusters might be called good matches, that is, activities or modes for which the students report that they do like and do learn at high levels. We should not only retain these activities, but continue to try to build more learning opportunities into these memorable experiences as appropriate. Having identified these clusters as being received so well, we can also try to capitalize on the students' positive perception levels to improve other areas of the course. This may be achieved by providing more reflection or possibly tying more activities to these modes, such as the textbook, so that even if another lower rated activity itself doesn't change, if combined with a High/High activity, the High/High activity's popularity may provide a lift in the others' rating and concomitant effectiveness.

At the other end of the spectrum are the Low/Low Clusters –bad matches– reflecting what the students like less, and report that they learn less. It is interesting to note that the three learning modes that fall into this category, *Textbook*, *Directed Research*, and *In-Class Review*, all heavily target the verbal learner. This Low/Low result is not surprising since the verbal learning style is certainly not the most common style seen in the classroom while it tends to be the most common style used by professors. Using the Kolb Learning Style Inventory[9] identified above, we clearly need to help the students develop better strategies to adjust and compensate for this less preferred learning style.

As suggested above, one change that we can consider is connecting and integrating any of the indispensable low modes with the features of the more favorable modes. For instance, the textbook, which is a benefit to the verbal, intuitive learner and –to a lesser degree– the reflective learner, can easily target other learning styles through the considered selection of homework problems, laboratories, and activities associated with the reading material. In fact, all of the learning styles may be reached directly or indirectly through thoughtful use of the textbook. Likewise, the *In-class Review*, if retained, may have the opportunity to reach other learning styles such as the visual, active or reflective learner by using teaming, active matching exercises, or review sheets.

As for *Directed Research*, an emphasis on the importance of information gathering and how it relates to being a successful problem solver must be made. Furthermore, the research work should be either used immediately or be driven in part by student interest for the learner to realize the value in this mode. First-year students are prone to compartmentalizing and may not see the merit in such an activity as yet, so that interest needs to be generated for them. A different approach may be to turn the exercise into a teaming activity in which case active learners will be inspired from the people interaction. Reflective learners may become more actively involved when the data found needs to be reduced and compiled into a report.

Finally, the goal is not necessarily to match and cater to the primary learning style of the population in all cases[23]. This has a two-fold consideration. First, the "primary learning style" by definition does not mean the "only learning style", so to provide for it alone is to miss some. Second, in order to develop intellectually, learners should also be challenged along the dimensions which do not represent their preferred inclination toward learning. Being educated through a variety of learning styles has the potential to create a more rounded engineer. Again, this is the balance we seek; this research has contributed to our discernment and hopefully course development in these areas.

Summary, Recommendations, & Conclusion

Summary. Reflection is found at the end of the chain of stages that make up the design process, yet we as educators are reminded that it is also the link to ensure there is ongoing development for both the students and the course. This research came about because having invested in active learning, having previously established a clear and measurable effect reported amount learned[2], and being committed to making it a principle component of the engineering curriculum at NU, it was again time to pause to consider, "Where to from here?" The results from this research show that engagement and learning are highly correlated on many design course items, but not all. The quantitative and qualitative results strengthen our belief in *selective* active learning, with concomitant variety and balance to address all learning styles. Can we ever be certain our students are learning the most that they can from the course or activities? No, probably not, but this feedback certainly helps us decide what is working well, what we may keep, what might require some review, modification or improvement, and most importantly, from where any adjustments might be derived.

The results of this work show that we are doing well in many aspects; we determine that from the High Learning/High Engagement items. There are a number of these items, which generally are the projects that the team of instructors has spent time reviewing and revising over multiple years and it seems that time was well spent. We also see that students are capable of discerning the value of balance in multiple learning modes, even if they are unaware of the learning styles terminology or models. The results show us that our engineers feel they are learning from both activity-based projects and traditional lecture modes. This modal mixture addresses a variety of learning styles, and it seems that this fundamentally works.

What is also clear is that as engineering educators, we can still learn through "self" assessment of our established courses. There are modes that are not as high on learning ratings that we would like, even when they are engaging. This gives us the impetus to review and revise these activities. This is the case for the *Design Deconstruction* assignment and *Directed Research*, for which we are now looking for ways to optimize these projects and the associated work. Without this assessment, we may have been misled by the students' enjoyment of a task and not realized they did not perceive themselves as being educated by a particular activity. We will continue to use our faculty team approach to develop the engineering design course. Typically, this results in one faculty member trying something new and then providing feedback to the teaching team on its level of success[34]. Other options are to brainstorm and attend conferences looking for information and insights on ways to improve. However, this time when we use these other options, we also have our data to help us identify *areas* of need and possible solutions.

Recommendations. Prior to this analysis, data had also been collected from all of the recent instructing faculty for this course on their personal Learn/Like opinions for each mode and on predictions of how the students would respond from the learner's perspective. That data remains to be analyzed and interpreted in light of the student-centered results of this research. Also in terms of follow-up data, the next step is to poll the n^{th} subsequent generation to determine if any of our adjustments have been effective. Albeit a new population may possess entirely different expectations and values as a whole, but that has not been our experience in year-to-year spans.

We recommend this detailed course reflection as a worthwhile activity to other educators. While it is time-consuming to carry out, this is more than sufficiently compensated by the fresh sense of direction and heading it provides for future work. In evaluating our course landscape, we bear in mind that different learning modes exhibit a mixture of high and low values on the Like-Learn continua. Thus while one learning mode might become more effective with greater focus on education, another might benefit from being perceived as more engaging. It is being able to evaluate these measures and variations that will enable us to propose teaching strategies to make learning more effective.

Conclusions. Finally, the overriding lesson to be derived from this work has been a greater understanding of the value of 'value'. It must be perceived and appreciated by the students for an educator to make significant progress on the path to effective education. Being able to identify when the perception of value exists naturally and when it might require guidance is a skill to be nurtured in educators. To this end, while we cannot identify a single causal factor for success – engagement or education– what we have observed and measured is that the lower an activity rates in either of these categories, the less effective that activity is as a means of promoting learning. Thus, improvements can only come from first identifying the perceived strengths and weaknesses of each category –and the learning modes found within– and adjusting accordingly. We have reinforced the fact that education and engagement are inextricably linked, and through the use of assessments and responsiveness, we may be better able to craft engaging and applicable engineering courses that ensure that the students' interest is maintained and the learning goals are realized in the process.

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Appendix A: Learning Modes Ratings Page from Survey Assessment Tool

Rate each of the following on (a) the degree to which they help you in learning and (b) how engaging or interesting each is on a 1-5 scale. Place n/a if it is not applicable in your class; Use a number for each option, 1=not at all; 5=very much You may use the same number twice since this is a rating, not a ranking.

The Learning rating is not merely about the *percentage* or *amount* you learned, but how well it helped you learn the concept/topic at hand.

The Interest portion is not merely about how *fun* the activity is compared to entertainment, but how engaging or interesting it is compared to other classroom teaching options.

Not at all	*Hardly*	*Somewhat*	*A Reasonable Extent*	*Very much*
1	2	3	4	5

LEARN		ENGAGE/INTEREST
________	*Engineering by Design* Textbook	________
________	Preparing and Presenting Case Studies	________
________	Seeing Case Study Presentations	________
________	Minor Design Project: Planning and Building	________
________	Minor Design Project: Preparing Demo and Demonstrating	________
________	Professor's Presentations and Explanations	________
________	Movie Analysis: Doing and Presenting	________
________	Movie Analysis: Viewing Presentations	________
________	In-Class Exam Review Activities	________
________	Directed Research Activities: (Internet, Patent Search, Site Visits, Interviews, etc.)	________
________	Design Deconstruction and Presenting Poster	________
________	Poster Presentations: Viewing and Evaluating	________
________	Teamwork/Team-Building Activities (Hanger Evaluation, Tower of Straws, Goals Consulting, etc.)	________
________	Major Design Project: The Process	________
________	Major Design Project: Preparing Presentation & Final Design	________
________	In-Class Practice ➔ Present Findings (Prob. Formulation, Goals Consulting, Abstraction & Synthesis, etc.)	________
________	Examples and Samples of Other Students' Work	________
________	Guest Speaker from Industry: Reebok®	________
________	Movies/Videos selected by the Professor	________
________	One-Minute Engineers: Preparing	________
________	One-Minute Engineers: Viewing	________

bki/sff/rw *Thank you*