Student Perceptions of Tactile and Virtual Learning Approaches: What Can We Learn from their Viewpoint?

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Abstract

Active physical manipulation and touching of objects, also known as tactile interactions, are generally viewed as effective ways for students to learn complex and abstract concepts. Researchers, however, are still investigating *how* tactile instructional activities contribute to deeper student learning. In traditional engineering design courses, students engage in tactile as well as virtual learning experiences. This study aims to determine whether substantial differences exist between *tactile* and *virtual* learning approaches on active learning outcomes. In this preliminary study, we are investigating students' perceptions of tactile and virtual learning activities in an engineering design classroom and the challenges that students face in performing these types of activities in a team-based approach.

Active learning can have many definitions and, in general, refers to various teaching and learning strategies where students are responsible for their learning by interactive involvement – this is not a passive lecture approach. With tactile learning, students are able to explore and manipulate objects and materials, yet today's students tend to do much of their exploration and object manipulation through the use of computer technologies rather than through interactions with physical products (e.g., virtual product dissection versus physical dissection). Some wonder if students who no longer touch and handle objects are able to be effective abstract thinkers. Others contend that because today's students are more tech savvy, active learning is possible through virtual interactions.

Our freshman students are introduced to engineering design in a course that incorporates both digital and hands-on learning. This class provides students with theoretical fundamentals, abstract thinking, and real-world applications that are taught through the framework of sustainable design and environmental awareness. Students work in teams to complete their lab assignments and their ability to successfully collaborate, use the various technologies, and create novel solutions is dependent upon their ability to manipulate objects (either physically or virtually). In this paper, we offer preliminary evidence on the comparison of tactile to virtual learning as perceived by our students and share instructional issues that students feel either help or hinder their ability to learn.

1   Introduction

Given that there are numerous ways to define engineering design, it follows that there are many pedagogical approaches to teaching design. While most agree that "design, above all else, defines the difference between an engineering education and a science education" [1], design experiences in the curriculum are varied and uneven. Many students report that design methods

are typically taught at a high-level and in a compartmentalized fashion resulting in students lacking incremental concrete experiences [2].

Today's educators are faced with not only pedagogical concerns when it comes to teaching engineering design, but they also need to adapt their strategies to best meet the needs of today's students. Many, if not most of the current crop of undergraduate engineering students, are less likely to be "tinkers" than students of earlier generations. "That tinkering by the way is early development of the ability to conduct critical analysis, an ability that is at the heart of engineering" and students who enter engineering classes without it need hands-on classroom experiences to overcome this deficit [3].

This generation, born between 1982 and 2002 known as the Millennials, are identified by Howe and Strauss as sharing these seven predominant characteristics: special, confident, conventional, sheltered, team-oriented, achieving and pressured [4].What is more telling, however, among this age group aptly labeled "digital natives" by Prensky is their comfort and dependence upon digital technologies [5]. The technological capabilities of Millennials are recognized by many and prompted Taylor to coin the term "technoliterate" to describe their unique perspective [6].While Millennials are known to lead lives infused with technology, this is still a diverse group of approximately 80 to 100 million Americans, who differ when it comes to specific technologies. We cannot assume that millennial students will all have the same learning aptitude with technologies nor will they all have the same desire to use these technologies [7,8].

Not only are the students' backgrounds and expectations changing, there is a greater emphasis on classroom instruction that is active and involves the learners. While teaching methods that promote student participation and active learning are often advocated, the term "active learning" is not always clearly defined. Most educators assume that learning is inherently active; yet research suggests that for students to be actively learning, they need to do more than just listen. As such, "it is proposed that strategies promoting active learning be defined as instructional activities involving students in doing and thinking about what they are doing [9]." Often people assume that learning involves a hands-on component, but that is not a necessity. Hands-on learning, however, can be active and involve thinking that goes way beyond mere manipulation of objects.

The relative effectiveness of hands-on instruction is a topic much discussed in a variety of disciplines. Engineers, in particular, question whether or not students benefit from tactile learning experiences and whether or not these experiences need to involve physically handling objects or whether digital techniques have the same impact. To clarify, *digital* learning techniques refer to the use of technology and virtual infrastructure to communicate concepts and activities relating to a course or curriculum while *tactile* or haptic learning relates to the physical handling of an object. In either case, the learner's hands are active and in use.

According to Taylor, Lederman, and Gibson [10], something touched is more real than something seen. Instructors in the sciences often espouse that active and physical manipulation is more effective when learning complex and abstract science concepts [11]. Manipulation when it involves intentional actions on the part of the learner can be motivating and increase attention to learning [12]. Yet current research still cannot attribute how concrete, tactile experiences contribute to understanding science.

Engineering educators question how much, if any, virtual experiences can replace hands-on learning. While there is not general answer to this question[13], there does seem to be consensus that engineering students often have an aptitude for visual and tactile learning[14] and that students need these types of experiences to learn engineering. One area that has received considerable interest is how drafting helps students develop 2D and 3D visualization skills. There is evidence that hands-on problem solving influences improved spatial abilities[15] and that the cognitive processes used to physically draw a line are different than those that are needed to specify the end points for a CAD representation [16]. A survey found that industry practitioners, faculty and students believe there is value in learning how to construct technical drawings using a pencil and that 'the haptic experience of pencil and paper line production and layout, combined with the discipline of using orthographic and axonometric projections appears to engender a deeper appreciation of accepted conventions [16]."

Some suggest that engineering students are dissatisfied with flat, non-engaging instructional approaches and tools. A review of engineering mechanics projects found that none employed haptics for the feel of forces involved [17]. With "feeling as believing" as their guide, a group of Ohio State researchers developed a haptic interface to a set of software activities used by engineering undergraduates and they found that students did gain a better understanding of thebasic course concepts [18]. The purpose of this study is to probe student perceptions of digital and tactile learning techniques. Do students have a preference for either of these approaches? Do they believe that deeper learning occurs based on whether or not they were using digital or tactile techniques? Gathering input on students' perceptions is an important consideration [19] as these perceptions can affect student engagement and learning [20]. It is noteworthy that if students perceive a particular approach positively, they are more motivated to learn and will believe they will learn more [21]. If professors are aware of students' perceptions of digital and tactile learning, they may be better able to design instruction that promotes deeper student learning.

2   Course Description

Introduction to Engineering Design (EDSGN100) is a first-year engineering design course, required for most engineering majors at Penn State University. The class employs a design-driven curriculum with emphasis placed on skills such as team-based design, communication skills (graphical, oral and written), and computer-aided analysis tools. The course introduces students to the engineering approach to problem solving with strong references to basic science

and math skills, as well as testing and evaluation design ideas by building prototypes. The design projects are a total of at least 30 hours of in-class work (one-third of the course).

The course aims to teach students how to:

1. Use the design process well in all the course projects, ability to extend the design process to general problem solving, and assess the value of creativity in the engineering design process.
2. Develop basic skills in 3-D solid modeling CAD (Computer-Aided Design) using SolidWorks.
3. Acquire 3D visualization skills to draw and communicate design ideas and concepts.
4. Contribute to team-based projects, solve inter-team problems and develop communication skills.
5. Produce a well-organized reports and virtual portfolios summarizing design project work

3   Overview of Engineering Design Project

Students are presented with a *sustainability-driven* project by first introducing them to the global impact of the current state of activities. Recent research published by the U.S. Environmental Protection Agency indicates that approximately 789 million mobile devices are at the end of their life, ready to be recycled. However, only about 11 % of those now considered "junk" were recycled last year. The rate of consumption of natural resources, coupled with the abysmal recycling statistics presents enormous challenges for future generations [22].

Student teams (approximately 4-5 students/team) are assigned the task of developing a concept for a new niche market for a sustainable consumer electronics product. Each student team is to develop new concepts for a sustainable consumer electronics product. Each student team is to analyze the current offerings in the market and design a product that will better meet needs of the targeted environmentally conscious/green population.

The external design activities include following steps:
>   Step 1. Analysis of customer needs
>   Step 2. External search (Product Dissection and Benchmarking)
>   a.   Component and assembly analysis
>   b.   Literature Review
>   c.   Patent Search
>   Step 3. Revising the design statement
>   Step 4. Internal work for concept generation
>   Step 5. Concept Generation (Conceptualization and Virtual Representation)
>   Step 6. Concept Selection
>   Step 7. Embodiment of the design and feasibility analysis
>   a.   Materials and manufacturing processes
>   Step 8. Detail Design.

Steps 2 and 5, while distinct in their methodological approaches, relate to the same design project, hereby enabling researchers to study student learning between these two steps (*tactile* VS *digital*). That is, when students are presented with an engineering design

objective (in this case, a sustainability focused project), they first engage in hands- on learning through product dissection/benchmarking (Step 2), followed by a conceptualization of their design solutions in a digital environment (Step 5). Steps 2 and 5 are allocated approximately 2 weeks of in-class time (~4-6 hours) each with the methodological distinctions made primarily based on the nature of the design task; *tactile* primarily focuses on *physical* interactions with a design artifact, while *digital* primarily focuses on the *digital* interactions of a design artifact.

3.1   Tactile Project Assignment: Sustainability-Driven Design

The *tactile project assignment* (Step 2) primarily focuses on *Product Dissection and Benchmarking.* Here, students physically interact with products/components of products for a more in-depth understanding of the configuration and interactions among product components. During the product dissection and benchmarking exercise, students:

1. Disassemble, measure, and analyze the function of each component. The data is recorded in the Bill of Materials (BOM) table created by students.
2. Insert pictures or sketch components to the visuals table in a data sheet. The names of the components are indicated in the data sheet.
3. Study and indicate (using a tree structure) how components, subassemblies, and final assembly relate to each other on data sheet 2.

 Table 1 provides a visual representation of the results from a student team's product dissection activity.

Table 1: Visuals: Component pictures, sketches and/or solid models

|		
Base	Top Handle (view from underneath)	Plastic Base
Circuit Cover	Top Handle (view from above) Handle	Casing
Spring	Zip Tie	Timer

As can be seen from Table 1, the product dissection activity is very *hands-on*, hereby establishing the *tactile* connection between a physical artifact and a student's understanding of its function/behavior. Students also engage in *tactile* activities during the actual construction of physical prototypes. Out of the 6 hours of in-class time spent on design related activities each week, students spend an average of 2 hours (33%) of the time working on *tactile* related activities such as product dissection, prototype construction, etc.

3.2 Digital Project Assignment: Sustainability-Driven Design

The *digital project assignment* (Step 5) involves the representation of student concepts in a digital environment. *Digital representation* of student concepts is a critical step in the design process as it allows students to visualize and communicate different ideas in a timely and efficient manner, prior to a final design being selected and physically built. The Digital Project Assignment steps include:

1) Create the 3D object with SolidWorks
2) Create a multiview drawing including the following views:
    i. Front View
    ii. Top View

   iii. Left View
   iv. Isometric View
   v. Detail Views
 3) Drawing Details:
   i. Fill the title block with student names and scale information
   ii. Include a note explaining the dimensions
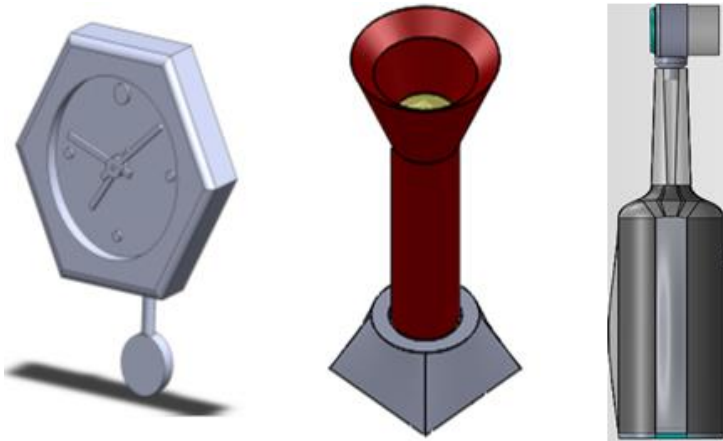
Figure 1: Example Solid Works models of student design projects

Figure 1 presents visual results of prototype CAD models that students have worked on during *digital* design activities. Out of the 6 hours of in-class time spent on design related activities each week, students spend an average of 2 hours (33%) of the time working on *digital* related activities. Each student is provided with his/her own computer with CAD software installed. Students can either work on sections of a CAD concept that then integrates with other sections design by other team members, or individually design and complete an entire CAD prototype from scratch and then compare different *digital* concepts within the team.

4 Description of Study and General Methodology

EDSGN100 is a course that is taught in multiple sections across various Penn State campuses. While there is a suggested text and activities, each professor has freedom to adjust their curriculum as needed. The two sections of this course participating in this study had different professors, but similar course requirements. Student participation in this study was voluntary. Since people who volunteer for a study may differ from non-volunteers, selection bias may exist.

With this preliminary study, action research (commonly known as research done by those in the field to improve their practice) was used. This research does not involve the use of a control group and is not attempting to make generalizations to other settings. The focus with action research is on gathering information that can be used to change conditions in a particular
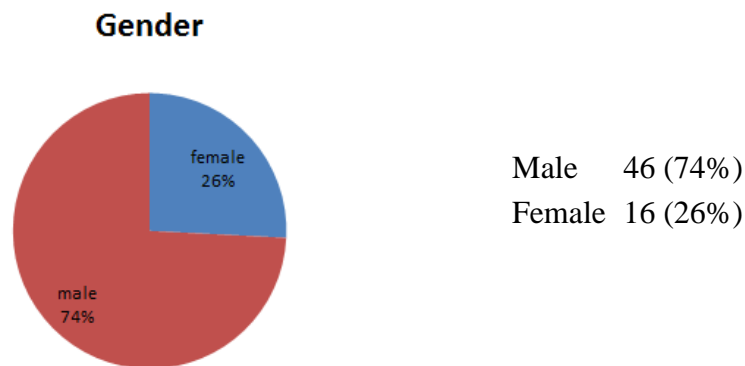
situation. Here we gathered information about the students and their perceptions on digital and tactile instruction and based on our findings, we will make adaptions to our pedagogy. Midway through the semester, students completed a questionnaire that included both open-ended and scaled, retrospective pre-post responses. They also responded to some basic demographic questions. Use of the retrospective design allows for learner self-reported changes in knowledge, preferences, confidence, behaviors, and attitudes since it can be difficult for people to assess their pre-program understanding or behaviors. This method can replace a pretest - posttest approach since it takes less time and avoids pretest sensitivity and response shift bias resulting from pretest overestimation and underestimation [23]. The retrospective method is nonetheless still limited due to the vulnerability to bias in self-reporting (both social desirability and accuracy) and by the limitations of individuals' ability to accurately recall over time.
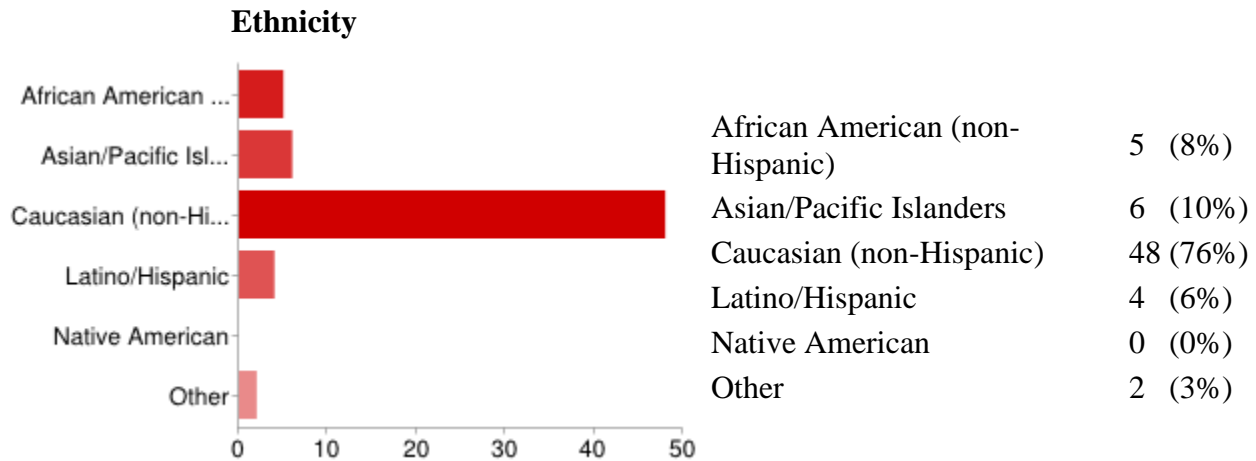
As described in the introduction, this study gathers students' perceptions via a questionnaire. Positive beliefs can influence student learning and this study aims to reveal how students react to digital and tactile learning approaches. By separating the *tactile* activities from the *digital* activities, researchers are able to clearly observe students' perceptions of the two domains of design education.

4.1   Description of the Population

Two classes, for a total of 62 students, participated in this study. As is typical in many engineering classrooms, there are notably more men than women. Given this is an introductory level course it is not surprising that 89% of the students are freshman. The racial/ethnic distribution is fairly representative since White, Asian, Black, and Hispanic are the four largest racial/ethnic groups among Penn State students. Slight variations may exist in the total number of student responses for the demographic related questions as some students do not feel comfortable providing this information and hence these questions, just like all questions were optional.

Table 2: Demographics of study: gender, class standing, and ethnicity

Gender

Male   46 (74%)
Female   16 (26%)

Ethnicity

|		
African American (non-Hispanic)	5	(8%)
Asian/Pacific Islanders	6	(10%)
Caucasian (non-Hispanic)	48	(76%)
Latino/Hispanic	4	(6%)
Native American	0	(0%)
Other	2	(3%)

4.2 Quantitative Survey Results

The quantitative analysis of the survey results aims to determine whether substantial differences exist between *tactile* and *virtual* learning approaches on active learning outcomes. In this preliminary study, we are investigating students' perceptions of *tactile* and *virtual* learning activities in an engineering design classroom and the challenges that students face in performing these types of activities in a team-based setting. The results below provide quantitative evidence of the correlations that exists between different variables (survey questions) in the survey. We have chosen to highlight Figures 2-5 (box plots of survey items 2- 5) because they are questions that are posed to reveal students' perception of both *tactile* and *digital* experiences. Table 3 presents the summary of the survey statistics for each item number (survey items listed 1-10) to help quantify the changes that are statistically significant.
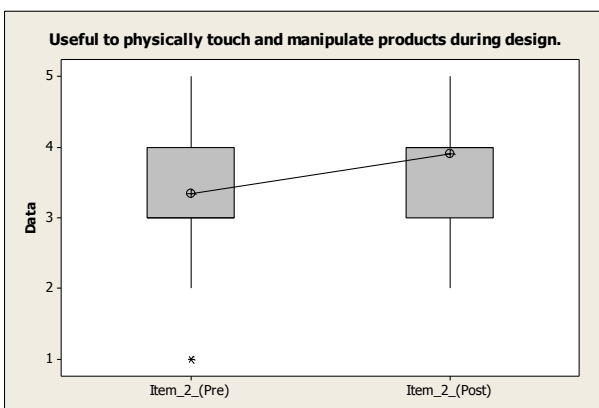
Figure 2: Item 2 Pre-Post
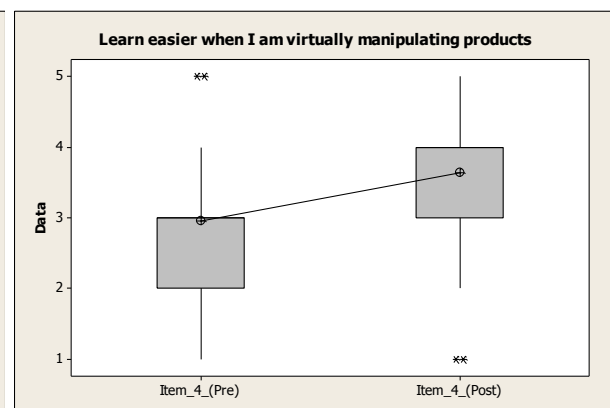
Figure 3: Item 4 Pre-Post
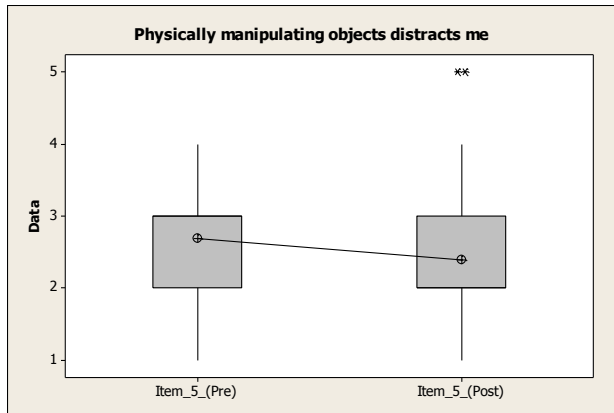
Figure 4: Item 5 Pre-Post
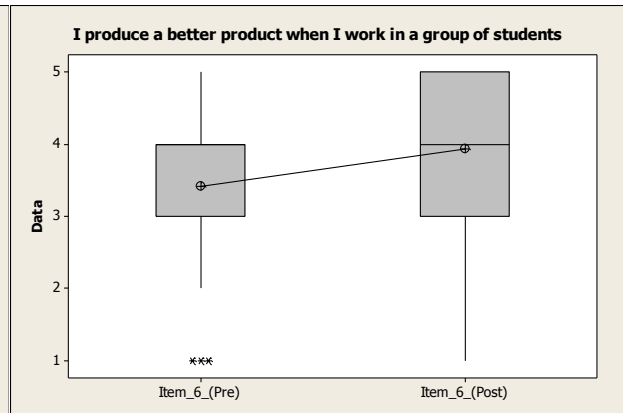
Figure 5: Item 6 Pre-Post

Table 3 provides the mean response values for the pre- and posttest for each of the survey questions. The T-value represents the results from the student's t-test which tests the null hypothesis that the means of the pre and post-test are equal. Once the T-value is calculated, the P-Value can then be determined and if a given statistical significance level (in this case 0.05), the null hypothesis is rejected. The F Statistic in Table 3 is simply another statistical test used to compare the variables in the regression model. The P-value is once again used to test for statistical significance, rejecting the null hypothesis if the P-value is less than the statistical significance level (in this case 0.05).

Table 3: Summary of Survey Statistics

Item	Survey Items	Pre-course Mean	Post-course Mean	T-Value	P-Value	F Statistic	P-Value
1	My knowledge about the environmental impact of a product.	2.468	3.532	-7.78	**0.000**	1.12	0.660
2	I find it useful to be able to physically touch and manipulate products when I am doing engineering design.	3.339	3.903	-3.63	**0.000**	1.91	**0.013**
3	I find it useful to be able to virtually manipulate products (using tools like Solid Works/CAD, HTML/Google, etc.) when I am doing engineering design.	3.339	4.194	-5.22	**0.000**	0.97	0.891
4	I find it easier learning when I am virtually manipulating products	2.952	3.650	-4.12	**0.000**	0.72	0.205
5	I find it that physically manipulating objects (such as product dissection, campus tours, 3D scanning and printing) distracts me from focusing on the assignment	2.694	2.387	2.11	**0.037**	0.79	0.352
6	I produce a better product when I work in a group of students	3.420	3.940	-2.82	**0.006**	0.93	0.776
7	Seeing a visual helps me make connections between what I know and new intangible material that I am learning	3.855	4.210	-3.64	**0.000**	1.93	**0.011**
8	Manipulating something physically helps me make connections between what I know and new intangible material that I am learning.	3.806	4.177	-3.99	**0.000**	1.17	0.531
9	The use of virtual tools and technologies hinders my learning in this class	2.258	3.060	-4.53	**0.000**	0.94	0.801
10	In this class it is beneficial to have alternative ways of understanding the ideas or skills	3.645	4.268	-5.44	**0.000**	1.20	0.483

4.3   Qualitative Survey Results

In addition to the scaled responses, students were asked open-ended questions that allow students to respond based on their belief systems rather than solely responding to questions responses that are influenced by the researchers' parameters. These questions along with representative comments are provided below in Table 4. As the comments indicate, students came into the class with computer skills, ranging from basic operational use to more advanced skills including some

use of CAD. Only a few of the students have practical hands-on experience although several noted their usage of LEGOs and modeling clay. Group work and Solid Works were noted as having an impact on their learning.

Table 4: Qualitative statements provided by the questionnaire

Questions/Responses	Illustrative comments
What computer skills, if any, did you bring into this class?	"I know how to use computers." "Basic proficiency with all Microsoft Office programs along with a small amount of CAD." "I'm your average, *skilled* computer user." "I'm good with fixing problems and navigating an OS." "Some prior work in AutoCAD plus computer repair."
What hands-on experience, if any, did you bring into this class?	"I designed a chair from cardboard." "I have worked on cars and have built chairs, ice rinks, and houses." "None, but I'm good with LEGOs and modeling things with clay and such." "I am an avid model rocket builder."
List three things you have learned in this course.	"How to use Solid Works." "How to generate ideas." "How to work in a group to design something."
Briefly describe the instructional methods that were the most helpful to you.	"Comparing all the ideas that were generated from members in my group." "Practice with Solid Works." "Class discussions." "Even though I hated them, all of the presentations were extremely useful." "The tutorials were probably the most beneficial to me because I had no prior experience using CAD."

6   Discussion
The pre and post correlations were evaluated separately with the results presented below. Pearson correlation and regression analyses were completed in Minitab Statistical Software.

Pre-course:
1. Item2 is correlated to Item3.
2. Item 4 is correlated to Item3.
3. Item 5 is correlated to Item4.
4. Item 6 is correlated to Item4.
5. Item 7 is correlated to Item2.
6. Item 8 is correlated to items 2 and 3.
7. Item 8 negatively correlated with Item 5.
8. Item 8 correlates to Item 7.

9. Item 9 correlates with Item5.
10. Item 10 negatively correlates to Item 5.
11. Tactile skills correlate to Item 2.
12. Digital skills correlate to Item 4.

Post-course:
1. Item2 is correlated to Item 3.
2. Item 7 correlates to Item 8.
3. Digital skills negatively correlate to Item 7.
4. Gender correlates to Item 7.
5. Gender negatively correlates to Item 8.

Given these results above, we feel that the pre-course correlations are impacted by the notions of self, which might be over- or under emphasized; thus, less reliable in nature. Consideration of the just completed course activities makes it clearer for the respondents to isolate their salient perceptions. Accordingly, using only the post-course data we investigated the impact of tactile, digital skills and gender for their impact on students' perceptions. We have evidence of significant tactile skills on Item 2 (I find it useful to be able to physically touch and manipulate products when I am doing engineering design). And, we have evidence of significant negative gender effect on Item 7 (Seeing a visual helps me make connections between what I know and new intangible material that I am learning).   That is,

- **The higher one's tactile skills, the higher the likelihood for them to perceive that physical manipulation is useful.**
- **Females are more likely to have the perception of "**Seeing a visual helps me make connections between what I know and new intangible material that I am learning" (Item 7).

In terms of the qualitative data in Table 4, students with prior experience seemed to have acquired such knowledge independent of structured classroom settings. Activities such as "working on cars" or "building models" were frequently expressed as the pathway to acquiring these *tactile* experiences. On the other hand, students that had *digital* learning experiences seemed to have acquired such knowledge in a more structured learning environment such as in-class sessions or workshops. Such insight sheds light into the potential accessibility of different learning approaches and may help instructors better understand how to structure different learning activities (I.e., perhaps a more open-ended process for *tactile* activities while a more structured process for *digital*).

7   Conclusions

The use of tactile and virtual learning approaches is common in engineering design courses.
In this paper we present an analysis of student surveys collected during a recent offering of an introductory engineering design course. Although one survey was used, we were able to collect both pre- and post-perceptions by using retrospective questions. The results suggest that students find manipulation of objectives, both physically and virtually, instructional useful. It is their preference for hands-on, tactile experiences that needs further exploration. Given that we often

think of today's students as "digital natives" we may be making inaccurate assumptions about their learning preferences. We also found that gender may have an influence on students' preferences for the use of visuals in instruction. Our initial study will be useful as we further explore these issues and as we include student performance outcomes related to the use of tactile and virtual learning experiences.

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