STUDENT PREFERENCES ON TACTILE VERSUS DIGITAL LEARNING: IMPLICATIONS FOR CONCEPTUAL DESIGN

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ABSTRACT
Given the potential diversity of our engineering students in terms of their preparation to complete engineering design tasks, we sought to understand the implications of digital versus physical preferences in manipulating objects while completing computer aided design (CAD) tasks. We speculated that today's students who are more technology savvy would be better in virtual/digital environments (i.e., comprehension and virtual manipulation); on the other, we thought that although helpful virtual/digital experiences would not be as concrete as literally working with products, and thus the need for this additional level of concrete comprehension would be salient. Using a subject pool of 54 students, we have completed timed, in-class experiments to study our hypotheses. Results indicate that indeed some engineering students have strong preferences/comfort with virtually handling products, and for those students, timed design exercise where the interaction with the designed product was through only digital means, the performance was higher. On the other hand, student responses to questions relevant to physical manipulation of the product highly correlated with their perceptions relevant to manipulating products virtually; thus, we speculate that this points to the learning from "tinkering" in general, where students do not distinguish between the means -- virtual or physical. Further (qualitative) research is needed to substantiate this however. The results of this study have implications for how solid modelling courses can be designed to be more inclusive in nature to account for learning preferences.

Keywords: Tactile learning, virtual learning, performance comparison.

1 INTRODUCTION

Well established engineering curricula around the world employ techniques of *digital* and *tactile* learning and delivery methods to communicate complex engineering concepts. *Digital* learning techniques refer to the use of technology and virtual infrastructure to communicate concepts and activities relating to a course or curriculum. In this context the digital interaction with a design results in a student being able to see it on a computer screen (as a picture file, or a Computer Aided Design (CAD) file), which can be manipulated only through the input devices to a computer (touchpad, mouse, etc.), without a literal touch to the object. *Tactile* or haptic learning on the other hand relates to the physical handling of objects (Lowenfeld, 1945), and in this context it will mean that students can go beyond visually observing to being able to literally touch and handle the object and its components (e.g., feel the texture, weight, vibration, disassemble components, hear if it makes any noise, etc.).

Together, these two learning media are critical to the development of world class engineers who typically employ digital simulation techniques in order to create real life, tangible systems.

With the research presented in this paper we aim to determine whether significant performance differences are induced due to student preferences on *tactile* and *digital* learning. In this preliminary study, we are investigating students' perceptions of tactile and digital learning preferences in an engineering design classroom and the challenges that students face in performing solid modelling tasks.

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 vs. physical dissection). Some wonder if students who no longer touch and handle objects are able to be effective abstract designers. Others contend that because today's students are more tech savvy, learning in digital means can be preferred.

Fifty-six engineering students are introduced to engineering design in a course that incorporates both digital and hands-on learning. In this paper, we offer preliminary evidence on the comparison of tactile vs. virtual learning as perceived by our students; and share the results of an experiment, where same student subjects completed two solid modelling tasks – the first required exposure to the object through literal means, and the second was introduced digitally only. Below we first provide a summary of our literature review that led to the development of our hypotheses, and then we present the experimental design along with results.

2 LITERATURE REVIEW

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" (Hodge and Steele, 1995), 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 (Wood et al., 2001).

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 (Janosz, 2011).

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 (2000). What is more telling, however, among this age group aptly labelled "digital natives" by Prensky, is their comfort and dependence upon digital technologies (2001). The technological capabilities of Millennials is recognized by many and prompted Taylor to coin the term "technoliterate" to describe their unique perspective (Taylor, 2005). While Millennials are known to lead lives infused with technology, this is still a diverse group of approximately 80 to 100 million Americans and they have differences 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 (Oblinger, 2008; Lewis and Khan, 2001). Current generation of students who grew up with the internet and digital social connectivity (through e.g., social networks such as Facebook) have less exposure to the physical world (Kraut et al., 1998). With constant diversions from status updates, emails and other digital media, the so called *Net Generation* faces seemingly inevitable attention deficit challenges as well (Carlson, 2005).

Despite their technoliteracy, many believe that students are even less prepared to do well in engineering today, lacking the experience and intuition that develops from "hands on" activities from adolescent years (Ferguson, 1993; Rossi, 2012) as engineers long have been considered to be predominantly "active, visual learners", much better served by active, visual and tactile teaching methods (Felder and Silverman, 1988; Svinicki and Dixon, 1987; Meyers and Jones, 1993). Consequently, development of in-class product dissection and reverse engineering activities has been motivated, in part, by a general agreement among U.S. industry, engineering societies, and the federal government that there has been a decline in the quality of undergraduate engineering education over the previous two decades (Fincher, 1986; Nicolai, 1995). Interest has since increased in providing both intellectual and physical activities (such as dissection) to anchor the knowledge and practice of engineering in the minds of students (Brereton, 1998; Lamancusa et al., 1996; Brereton et al., 1995).

3 EXPERIMENTAL DESIGN

As the core idea for the experimental design, we thought that today's students are more technology savvy potentially making them better in virtual/digital environments (i.e., comprehension and virtual manipulation); we also thought that although helpful virtual/digital experiences would not be as concrete as literally working with products, and thus this additional level of concrete comprehension need would be salient. We have chosen to test engineering students' performance in an introductory engineering design course; more specifically, using computer aided design (CAD) tasks. A total of fifty sixty students completed the CAD tasks one of which was introduced in physical means while other was presented only in digital means. The same group of students was also invited to complete a survey that registered their preferences.

Figure 1 presents a visual representation of the experimental setup used to assess student learning. The design artifact used in the experiment was a physical coffee mug. Each student was provided with a physical coffee mug (navy blue in the image shown in Figure 1) and asked to interact with the design artifact. Students were then tasked with designing a digital representation of the physical design artifact.

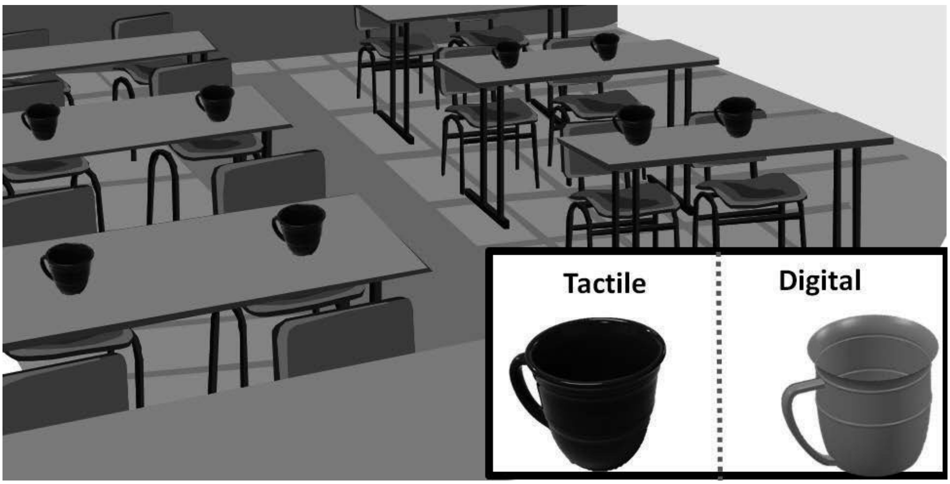

Figure 1. Digital VS Tactile Experimental Setup

Students also responded to the following survey questions, for which responses were given either as open-ended or using a 5-point Likert scale. The survey questions that are discussed in the paper are provided below. Note that the last two had open-ended responses, which were then coded so that statistical analyses could be performed.

I find it useful to be able to **physically touch and manipulate products** when I am doing engineering design. (***Factor A, tactile***)

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 (***Factor B, digital/virtual***)

I find it easier learning when I am virtually manipulating products (***Factor C, digital/virtual***)

I find that physically manipulating objects (such as product dissection, campus tours, 3D scanning and printing) distracts me from focusing on the assignment requirements (***Factor D, tactile***)

Seeing a visual helps me make connections between what I know and new intangible material that I am learning (***Factor E, digital/virtual***)

Manipulating something physically helps me make connections between what I know and new intangible material that I am learning (***Factor F, tactile***)

The use of virtual tools and technologies hinders my learning in this class (***Factor G, digital/virtual***)

What **computer skills**, if any, did you bring into this class? (***digital/virtual experiences, coded as Factor Digital experiences***)

What **hands-on experience**, if any, did you bring into this class? For example, model building or working on a car. (***tactile experiences, coded as Factor Physical experiences***)

4 RESULTS

Collected results were analyzed using Minitab 16, a statistical analysis software. First a correlation analysis was done for all factor pairs to screen out the highly correlated factors before the regression analysis. This analysis also revealed that Factor A was significantly correlated to prior tactile experiences ($p=0.026$), revealing that students were consistent in their preferences of tactile learning

as identified by their prior exposure.
Then regression analyses were completed to explain the variation in CAD performance where virtual and physical interaction means were tested. For example, digital/virtual relevant survey factors along with gender were regressed to investigate their capability in explaining the variation in CAD performance where the interaction with the designed artifact was in digital means (V-Performance). As shown in the following regression model and the following ANOVA with the T and p values, factor B was found be significant with (alpha = 0.1); the higher the students found the virtual manipulation the better their CAD performances were. The other significant factor for the V-Performance was gender, where the performance scores were higher for male students.
The regression equation for the virtual performance case is (R^2= 45.7%)

V-Performance = 60.7 + 5.72 B - 0.31 C - 2.58 E - 1.71 G + 0.03 Dig-Ex + 14.0 Gender

Predictor	Coef	SE Coef	T	P
Constant	60.72	21.05	2.88	0.008
B 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	5.719	3.086	1.85	**0.076**
C I find it easier learning when I am virtually manipulating products	-0.306	2.218	-0.14	0.891
E Seeing a visual helps me make connections between what I know and new intangible material that I am learning	-2.585	4.527	-0.57	0.573
G The use of virtual tools and technologies hinders my learning in this class	-1.711	1.946	-0.88	0.388
Dig-Ex (Digital Experience)	0.027	1.317	0.02	0.984
Gender	14.032	5.171	2.71	**0.012**

When the similar regression analysis was done for the CAD performance during which the artifact interaction was through physical means (see Figure 1), no significant factors was found for their impact. We refer to CAD task performance where the interaction with the design is through physically handling the real object in Figure 1 as P-performance, and if the interaction is only through a digital file, it is referred to as V-Performance. A further analysis of the scores revealed that the average score for this P-Performance was 92% whereas it was 82.12% for the V-Performance; in other words, perhaps the variation in the P-Performance was too small to be explained through other factors (see below). We note also that the V and P performances of the students were significantly different as seen by the non-overlapping confidence intervals below.

Variable	**N**	**Mean**	**StDev**	**95% CI**
P-Performance	27	92.00	10.18	(87.97, 96.03)
V-Performance	32	82.13	11.74	(77.90, 86.36)

5 CONCLUSIONS & FUTURE WORK

The experiment presented herein intended to understand the preparation and preference of engineering students on digital versus tactile experiences and their relevant performance in CAD using digital and or tactile means as they interact with products. Our results point to significant implications of relevant preferences of manipulating products in a virtual way on CAD performance with virtual interactions. Of note also is the significantly higher success of male students in virtual CAD performance. Although we have not found similar significant differences in CAD performance for which the interaction was in physical means (P-Performance), we suspect the limited variation in these values as a barrier; thus, we will replicate the overall experiment with a perhaps more difficult product to be modelled.

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