AC 2007-2664: THE EFFECT OF STUDENT TABLET PC USE ON THEIR ATTITUDES TOWARDS AND UNDERSTANDING OF CONCEPTUAL DESIGN

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The Effect of Student Tablet PC Use on Their Understanding of and Attitude toward Conceptual Design

Abstract

Engineers who work in innovative design spaces during conceptual design have very different CAD and graphics needs than those who work in more conventional design spaces such as those of detail design.[1,2] They need rapid, parsed communications, which support rather than constrain creativity. We have been examining digital ink technologies such as digital ink pens, SMART Boards, and Tablet PCs (TPCs). We have been exploring these since 2004 in the context of a program offering an introductory engineering design course to about one thousand students a year and upper division courses in innovative and global design. We will report on our initial examination of using TPCs in student design teams.

This paper reports on a nonrandomized control-group pretest–posttest study conducted at Penn State University. Half of a first-year design class used TPCs and half used traditional paper and pencil for part of the semester; the groups then switched tools. It is hypothesized that TPC use by engineering students will have a positive effect on their understanding of and attitude towards conceptual design. An instrument designed to collect information on student awareness of the design process was developed and administered as a pre- and post-test. Results of this test will be reported, and suggestions for further research provided.

Background

Conceptual design is a very important stage in engineering design. It is "the thought process of generating and implementing the fundamental ideas that characterize a product or system".[3] A product or system's success depends heavily on activities in this stage. This is where innovative ideas are created and evaluated. There are different phases within conceptual design itself, most commonly referred to as user needs identification, concept generation, concept analysis, and concept selection. In the context of the complete engineering design process, conceptual design comes after problem development, and precedes embodiment design and detail design. Conceptual design is unique and very much different from detail design. Therefore, communication in the conceptual design phase is also very much different from communication in the detail design phase. In conceptual design, "the amount of information flowing, the diverse nature of that information, and the speed at which it flows is far greater than in detailed design."[1] For capturing this information, flexible graphical tools are needed. Regardless of the importance of conceptual design, design education tends to focus more on the detail design and much less on conceptual design. We find that it is important to help engineering students understand conceptual design, its importance, and its value in the engineering design process and be able to enjoy it and appreciate its importance. One of the means for enhancing students' understanding and enjoyment is through student use of tools that are rich in potential to facilitate conceptual design.

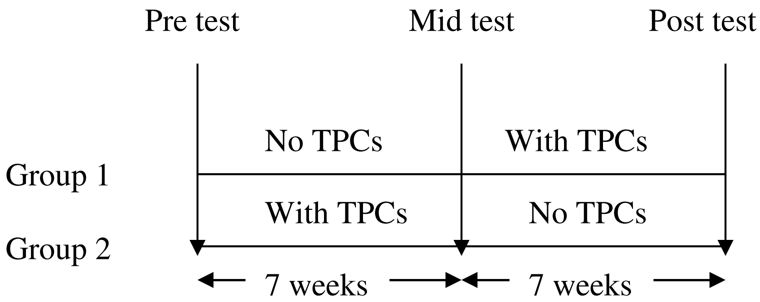
The TPC is one such tool that can enhance conceptual design and conceptual design communication. With its pen-based features, the TPC opens a lot of possibilities for transforming conceptual design, which is currently largely paper-based. It can help transform the learning of design and the process itself. With the TPC, students can interview customers and users to identify needs, and can communicate ideas spontaneously with sketches. Concepts can be generated quickly with digital ink on the spot and the ideas can be communicated with team members quickly and efficiently. Team members can give feedback by markup and annotation with the pen. The mobile nature of the TPC also allows the design team a more natural working environment (e.g., around a table or in a huddle) to work through concept selection, concept generation, and concept analysis.[1] All of these advantages can make the process more enjoyable, allow creativity to flow, and enable a deeper understanding of conceptual design. Even though TPC has not been used widely in education to date, many positive results have been reported from cases of TPC use in education across various fields with the majority of cases from higher education.[4] Student attitudes have been among the most measured constructs in TPC studies.[4] Students' attitudes toward learning with TPC have been shown to be positive.[5,6,7] Pen-based tools such as the TPC can enhance student understanding of the materials to be learned.[8] We predict that TPC use can improve student understanding of conceptual design as well as improve students' attitude toward conceptual design. In our study, attitude toward conceptual design is defined as the perceived importance and the enjoyment level of conceptual design.

Our study was set in the context of a first year honors course that teaches introductory engineering design.

Research Design

This study used a nonrandomized control-group pretest–posttest design to determine the effects of student TPC use on their understanding of and their attitude toward conceptual design in terms of their perceived importance and their enjoyment of conceptual design. The repeated measures approach was chosen in order to control for the influences of extraneous variables. A first-year honors engineering design class was divided into two groups. In the first half of the semester, group 1 did not have the TPC while each student in group 2 was loaned a TPC for their use inside and outside of class, i.e., it was "theirs". From the middle of the semester to the end of the semester, each student in group 1 had a TPC for use and group 2 no longer had use of the TPCs. The participants were measured three times: a pretest for both groups, a mid test (which served as a posttest for the first portion of the study), and a final posttest. The time period between two consecutive measurement times was about 7 weeks. This research design also guaranteed that all students in the course would have full access to a Tablet PC for a period of time.

Figure 1. Research Design



Participants and Setting

Participants included 25 students in a first-year honors engineering design class at Penn State. They were divided into 2 groups of 12 students (Group 1, with 8 males and 4 females) and 13 students (Group 2, with 11 males and 2 females). Each group included 3 teams. Students on each team worked together for two design projects throughout the semester. Each student in group 2 was given a TPC to use during the first half of the semester and each student in group 1 was given a TPC to use during the second half of the semester. However, the students were not specifically encouraged to communicate using the TPC other than they would normally do with a computer/laptop. This course is an introduction to engineering design for all engineering majors where students learn about the engineering design process, participate in group design projects, and practice design communication skills through graphical, verbal, and written means. In this course, the conceptual design phase was taught in the following manner:

The students were presented with lessons on conceptual design based on material from Ulrich and Eppinger (Chapter 4: Identifying Customer Needs, Chapter 5: Product Specifications, Chapter 6: Concept Development, and Chapter 7: Concept Selection). [9] These materials were reinforced through in-class examples and required as part of their design projects. Student teams were required to develop a minimum of 5 concepts that were communicated through annotated sketches. Through the design projects, and smaller design activities, students had opportunities to engage in all major phases of engineering design including problem analysis, conceptual design, embodiment design, and detail design. During the conceptual design phase, students used the different tools available to express their ideas.

Experimental Procedure

Teams were randomly assigned to either group 1 or group 2. At the beginning of the semester, students were given a set of surveys (pre tests) including an instrument measuring students' understanding and attitude toward different phases of the engineering design process. After that, each student in group 2 was given a TPC for use during the first half of the semester. They were also given training on how to operate the TPC and use some basic TPC-based software. Seven weeks later, students completed another set of instruments including the pre-surveys and two additional surveys. We called these "mid-surveys". At this time, students in group 2 gave the TPCs back and these TPCs were given to students in group 1. Seven weeks later, toward the end of the semester, students completed the post-surveys, which was the same set of instruments included in the mid-surveys. All the measurements were administered during class time.

Instrument (Appendix A)

We developed a questionnaire with 3 parts in order to determine the effects of TPC use on students' understanding of conceptual design, their perceived importance, and their enjoyment of the conceptual design phase. Part 1 asks students to state their understanding of all phases of the engineering design process: problem analysis, conceptual design, embodiment design, and detail design. Students wrote brief statements in this part. Part 2 asks students to rate their opinions regarding the importance of each phase and their enjoyment level of each phase, and part 3 asks students to rank the engineering design phases according to their importance and enjoyment level.

Part 2's questions are on 5-point scales with 1 being "Not Important At All" or "Not Enjoyable At All" and 5 being "Extremely Important" or "Extremely Enjoyable". Part 3's questions ask students to rank the stages of the engineering design process in order of importance from 1 to 4 with 1 being "Most Important" and 4 being "Least Important" or 1 being "Most Enjoyable" and 4 being "Least Enjoyable". The instrument has evidence of face validity but has not been tested further.

Findings

Analysis Method

The General Linear Model for repeated measures MANOVA in SPSS was used to test the primary hypothesis. Independent-sample t-tests were used to test for differences between the two groups at different measurement times, and paired t-tests were used to test the differences between the two consecutive measurement times for each group. All of the t-tests are 2-tailed.

Multiple independent samples t-tests showed that at the beginning of the semester there was no statistically significant difference between the two groups in their perceived importance and enjoyment of conceptual design as well as their perceived understanding of conceptual design. This means that the two groups were similar in their understanding of and perceived importance of conceptual design as well as their enjoyment level of conceptual design.

Understanding of Conceptual Design

Data analysis showed that TPC use does not seem to influence students' understanding of conceptual design. However, there are interesting findings in the sample of students. Detailed analysis with graphs follows.

One researcher rated the qualitative data from the open-ended question on the understanding of the conceptual design. Each student' perceived understanding of conceptual design was assigned a value from 1 to 4 based on the inclusion of the following processes in conceptual design: identifying user needs, concept generation, concept analysis, and concept selection. Inclusion of only one process yields a score of 1 and inclusion of all 4 processes yields a score of 4. Due to the importance of expressing ideas in sketches in conceptual design, another variable indicating the explicit inclusion of sketching in students' written understanding is added. This variable is given a value of 0 if there is no explicit inclusion of sketching and a value of 1 if there is explicit inclusion of sketching.

Table 1. Descriptive Statistics—Mean Scores for Understanding-Related Variables of Conceptual Design
(only data with scores in all 3 measurement times are included here)

Variables * CD: Conceptual Design		Pre	Mid	Post	Score Range (low to high)
Understanding CD*	Group 1 (11)	1.18	1.9	2.09	1–4
	Group 2 (8)	1.25	1.87	2.5	
	Total (19)	1.21	1.89	2.26	
Explicit inclusion of sketching in CD Understanding Statement	Group 1 (11)	0.36	0.18	0.27	0–1
	Group 2 (8)	0.12	0.5	0.37	
	Total (19)	0.26	0.31	0.31	

There is no statistically significant difference between group 1 and group 2 in both their perceived understanding of conceptual design as well as in the explicit inclusion of sketching at all measurement times. However, there is a difference in understanding between two consecutive measurement times for each group (see Figure 2). The perceived understanding of conceptual design seems to be influenced by time of measurement ($p = 0.004$). This influence, however, does not seem to come from the TPC use but more as the result of teaching since there is no interaction between time of measurement and TPC use. The trend line for the understanding of conceptual design is linear ($p = 0.003$).

There is a statistically significant difference between students' understanding of conceptual design at the beginning of the semester and in the middle of the semester for group 1 ($p = 0.021$), but there is no statistically significant difference for group 2 between consecutive measurement times.

Figure 2. Understanding of Conceptual Design

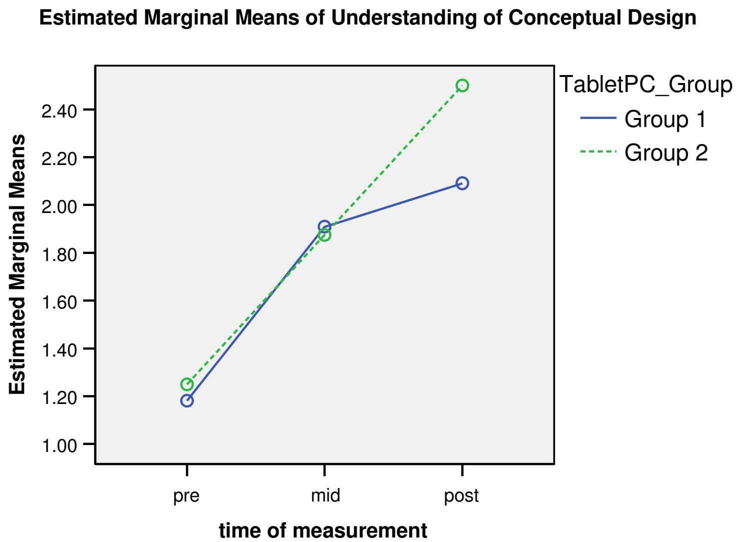
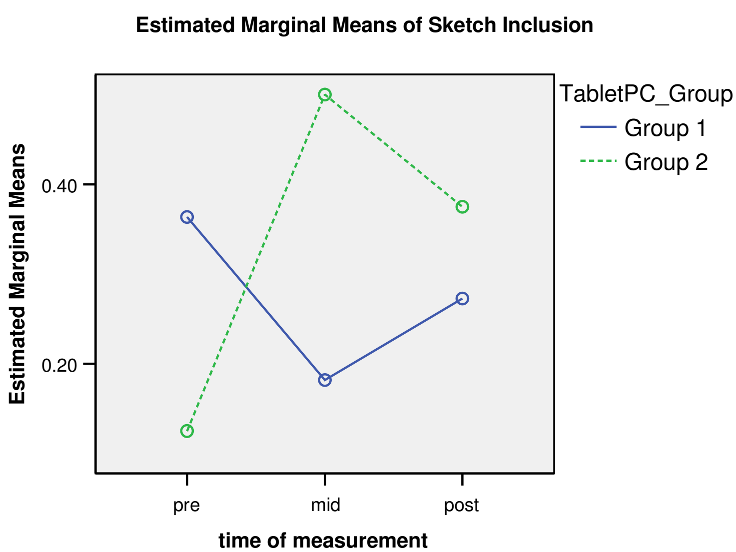


Figure 3. Inclusion of Sketching



In the sample, there is an increase in the explicit inclusion of sketching for group 2 in the middle of the semester and a decrease in the explicit inclusion of sketching for group 1 in the middle of the semester (see Figure 3). At the end of the semester, the situation reversed: the explicit inclusion of sketching declined for group 2 and increased for group 1. Is this because of TPC use?

Students' Attitude and Preference for Conceptual Design

The TPC seems to have no statistically significant influence on how students rated the importance of conceptual design and enjoyment of conceptual design. The TPC also seems to have no statistically significant influence on how students ranked the importance of conceptual design and enjoyment of conceptual design. Detailed analysis with graphs follows.

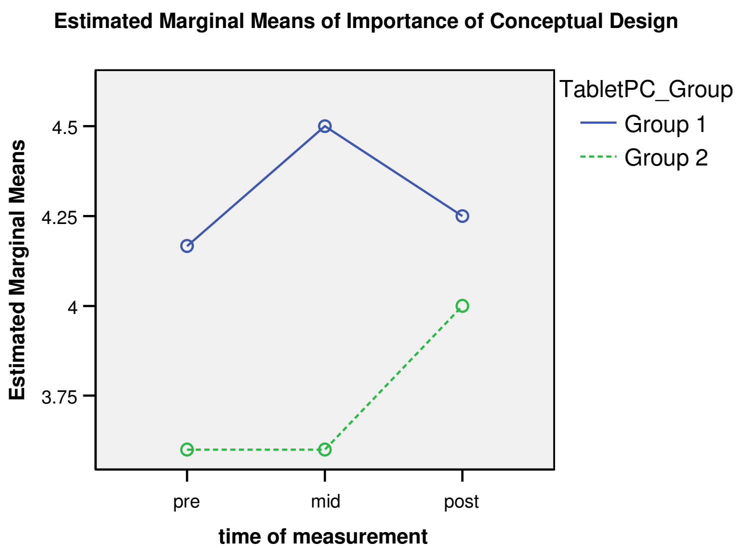
Descriptive Statistics. Table 2 shows the mean scores for attitude-related variables in the study.

Table 2. Descriptive Statistics—Mean Scores for Attitude-Related Variables of Conceptual Design
(only data with scores in all 3 measurement times are included here)

Variables * CD: Conceptual Design		Pre	Mid	Post	Score Range (low to high)
Importance of CD*	Group 1 (12)	4.17	4.50	4.25	1–5
	Group 2 (10)	3.6	3.6	4.00	
	Total (22)	3.91	4.09	4.14	
Enjoyment of CD	Group 1 (12)	4.17	4	4.17	1–5
	Group 2 (10)	3.7	3.7	3.5	
	Total (22)	3.95	3.86	3.86	
Importance Rank CD	Group 1 (12)	2.5	1.92	2.17	4–1
	Group 2 (9)	2.89	2.56	2.56	
	Total (21)	2.67	2.19	2.33	
Enjoyment Rank CD	Group 1 (12)	1.75	1.42	1.67	4–1
	Group 2 (9)	2.22	2.44	1.56	
	Total (21)	1.95	1.86	1.62	

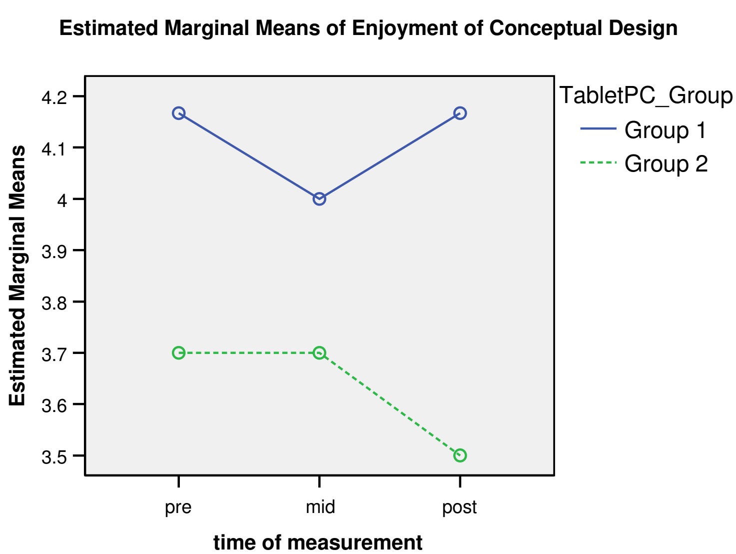
Importance of Conceptual Design. We hypothesized that the use of TPC will increase students' perceived Importance of Conceptual Design. However, the data showed the opposite. Group 1's Importance of Conceptual Design increased after the first half of the semester without use of the TPC and decreased after the second half of the semester, while Group 2's Importance of Conceptual Design (with use of the TPC during the first half of the semester) stayed the same after the first half of the semester and increased at the end of the semester (after the second half of the semester without use of TPC). Regardless, these results are not statistically significant for both group 1 and group 2. Therefore, the TPC seems to have no statistically significant influence on how students rated the importance of conceptual design.

Figure 4. Importance of Conceptual Design



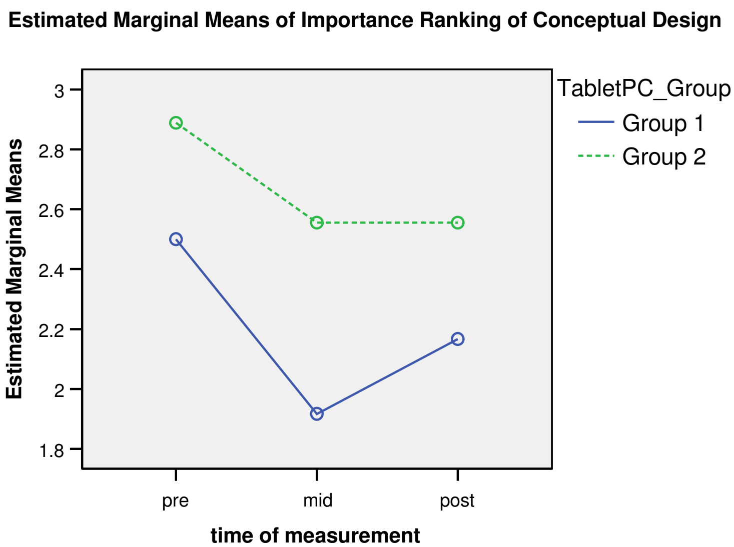
Enjoyment of Conceptual Design. Sample data showed that after the first half of the semester, group 1's Enjoyment of Conceptual Design decreased while group 2's Enjoyment of Conceptual Design stayed the same. After the second half of the semester, group 1's Enjoyment of Conceptual Design increased while Group 2's Enjoyment of Conceptual Design decreased. These results are not statistically significant for both group 1 and group 2. Therefore, the TPC seems to have no statistically significant influence on how students rated their enjoyment of conceptual design.

Figure 5. Enjoyment of Conceptual Design



Ranking of Importance of Conceptual Design. There is a statistically significant difference between the two groups in the ranking of importance of conceptual design compared to other stages of the engineering design process ($p = 0.037$). The differences between different measurement times are not statistically significant for group 1 and group 2 (multiple paired t tests). The TPC seems to have no statistically significant influence on how students ranked the importance of conceptual design.

Figure 6. Ranking of Importance of Conceptual Design



Ranking of Enjoyment of Conceptual Design. The differences between different measurement times are not statistically significant for group 1 and group 2 (t tests). The TPC seems to have no statistically significant influence on how students ranked the enjoyment of conceptual design.

Figure 7. Ranking of Enjoyment of Conceptual Design

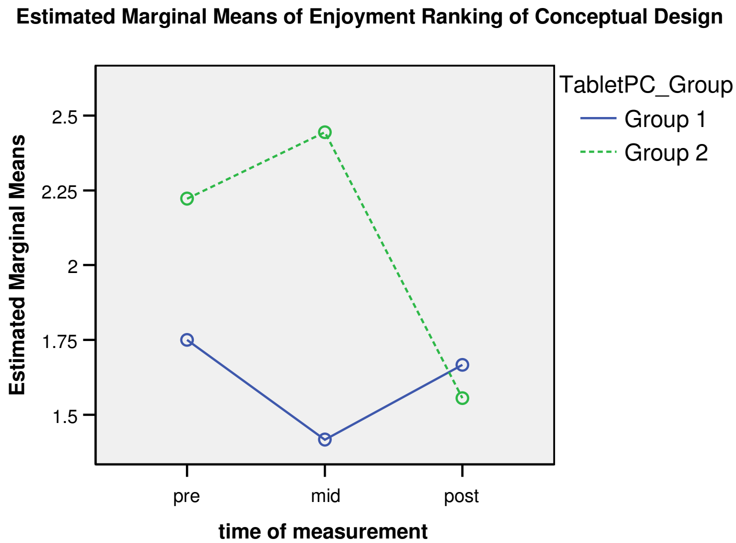


Table 3. Data Analysis Summary for Conceptual Design

Variables		Pre: Is there group difference?	Mid	Post	Generalization to Population
Importance of CD	Group 1	NS	+	–	NS
	Group 2		0	+	
Enjoyment of CD	Group 1	NS	–	+	NS
	Group 2		0	–	
Importance Rank CD	Group 1	NS	–	+	NS
	Group 2		–	0	
Enjoyment Rank CD	Group 1	NS	–	+	NS
	Group 2		+	–	
Understanding CD	Group 1	NS	+*	+	NS: there is training effect
	Group 2		+	+	
Explicit Inclusion of Sketching in CD Understanding Statement	Group 1	NS	–	+	NS
	Group 2		+	–	

CD: Conceptual Design
NS: not statistically significant at 0.05 level
*: significant at 0.05 level
+: increase
–: decrease

Discussion of the Findings

The findings were not able to confirm our hypotheses. There can be different reasons for these results. The foremost reason may be our approach of assigning a TPC and letting students adopt its use on their own. We did not specifically train students in using the TPC for doing conceptual design, so students may not know how to utilize the TPC for conceptual design. The TPC by itself cannot influence students' understanding or attitude. We need to embed pedagogy into TPC use. This is an implication for our future research: providing students with specific training in doing conceptual design using TPC. We also comment that adoption of TPCs in the broader student population may be hampered by lack of knowledge of their strengths and usage.

We think there may be a threshold effect in Tablet PC usage. There are a lot of new software applications to learn and use. Some users make the effort but many do not. For example, in another class one TPC per team was handed out to eight different teams. Over half of the enthusiastic students who volunteered at the beginning kept the TPC rather than handing it on to another team member as required for a second project. They wanted to keep it, and there were no new volunteers. Anecdotally, we hear of this effect in other venues and our next study should involve extensive training.

Another concept is regarding the students' characteristics. These students are honor students and we wonder if good students are less influenced by TPC use because of their intrinsic motivation to learn even without TPC.

Our small sample size (25 with 12 to 13 students in each group, limited by the number of TPCs available) can be a disadvantage in finding mostly statistically insignificant differences between groups and between different measurement times among each group. Especially for a treatment with possibly little effect like untrained use of TPC for conceptual design, we may need to have a bigger sample size to find statistically significant difference and for the statistical methods used to be justified. In addition, even though our research design gave every student in the course an opportunity to use the TPC for half of the semester while still maintaining a control-group pretest–posttest design, 7 weeks of TPC usage may not have given students enough time to make effective use of the TPC. We may need to have a different research design that gives students a longer time to use the TPC considering the limited number of TPCs that we have, the desire to give all students in the same course the opportunity to use the TPC, and the time frame of a semester. At the time of writing this paper, we are conducting a study that allows students to use the TPCs all semester. They are also required to explore and present software that supports the use of the TPCs during conceptual design.

Finally, the instrument used can also contribute to the insignificant results of the study. Our instrument needs to be further validated. It might be possible that, given part 2 of our instrument is on 5-point scale, increasing the scale to a 7-point scale may help to find more variance in the findings.

Conclusion

Even though there is an effect of training in student understanding of conceptual design, the study's findings revealed that TPC use without pedagogy cannot influence students understanding and attitude toward conceptual design. This prompts us to further our research by embedding pedagogy within student use of the TPC. A larger sample size may be needed and our instrument may need to be adjusted in order to see more variance.

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Appendix A

Perception, Attitude and Preference toward Different Stages of the Engineering Design Process

Part 1.
Please describe your understanding of the following stages in the engineering design process:

Analysis of Problem

Conceptual Design

Embodiment Design

Detail Design

Part 2.
Circle the appropriate level of importance of each of the stages in the engineering design process

	Not Important At All	Somewhat Important	Important	Very Important	Extremely Important
Analysis of Problem	1	2	3	4	5
Conceptual Design	1	2	3	4	5
Embodiment Design	1	2	3	4	5
Detail Design	1	2	3	4	5

Circle the appropriate level of your enjoyment for of each of the stages in the engineering design process

	Not enjoyable At all	Somewhat Enjoyable	Enjoyable	Very Enjoyable	Extremely Enjoyable
Analysis of Problem	1	2	3	4	5
Conceptual Design	1	2	3	4	5
Embodiment Design	1	2	3	4	5
Detail Design	1	2	3	4	5

Part 3.
Based on your opinion, rank the stages of the engineering design process according to their importance (1—most important, 4—least important):

Explain briefly why you have this ranking:

____Analysis of Problem
____Conceptual Design
____Embodiment Design
____Detail Design

Based on your opinion, rank the stages of the engineering design process according to your preference (1—most enjoyable, 4—least enjoyable):

Explain briefly why you have this ranking:

____Analysis of Problem
____Conceptual Design
____Embodiment Design
____Detail Design