Title:
Examining the Learning by Teaching Method in Computer-Aided Design Instruction

Authors:
Xiaobo Peng, xipeng@pvamu.edu, Prairie View Texas A&M University
Diwei Zhang, dzhang2@student.pvamu.edu, Prairie View Texas A&M University
Malcolm Jackson, mjackson58@student.pvamu.edu, Prairie View Texas A&M University
Bugrahan Yalvac, yalvac@tamu.edu, Texas A&M University
Antonia Ketsetzi, ketsetzi@tamu.edu, Texas A&M University
Deniz Eseryel, deserye@ncsu.edu, North Carolina State University

Keywords:
CAD, Learning by Teaching, Student-Centered Instruction

DOI: 10.14733/cadconfP.2018.11-15

Introduction:
Most of the current instructional strategies to teach Computer-Aided Design (CAD) software are teacher-centered. Students watch the demonstrations from their course instructors and then follow the directions to learn the CAD software. The students are kept in a passive learning role and they tend to memorize the procedures without thinking or self-reflecting. A review of literature has shown that student-centered learning environment is more preferred than the teacher-centered learning environment [1]. “Learning by Teaching” is one of the student-centered learning methods, in which students are assigned to take the teacher’s role and benefit from the activities implicit in teaching. Research has found positive results from the implementation of Learning by Teaching method, including deeper student understanding of the content knowledge, increased confidence, refined communication and social skills, changes in attitudes and motivation toward school, and higher responsibility [2]. Learning by teaching approaches have been applied in different engineering disciplines. However, few literatures can be found on applying Learning by teaching in CAD education.

A project has been carried out to implement the Learning by Teaching method in a freshman CAD class since Fall 2015. The project goal was to improve students’ learning of CAD, life-long learning skills, and engineering attitude. In this study, students were assigned in pairs to lead the teaching of the course content during the class meetings. Prior to the class meetings, the leader students learned and practiced the content by themselves outside of the class and designed an instruction to present the topic to their peers in class. This paper presents the data collected in four semesters to explore the effect of the Learning by Teaching method in the learning of CAD using both quantitative and qualitative data.

Methods:
The project has been implemented in a freshman "Mechanical Engineering Drawing" course sections offered in Mechanical Engineering Department since Fall 2015. The CAD software NX was used in the course. The research study conducted was a quasi-experimental pre-and-post test design. Data were collected from seven different sections in four semesters between 2015 and 2017. Two of these seven sections were designated as control group. Five sections were designated as experimental group. The students in the experimental group were assigned into groups. Each group consisted of three or four students. Each group (referred as tutors) was asked to take the teacher’s role and teach a CAD modeling exercise to the rest of the students (referred as tutees) during the class meeting. The tutors had one week to prepare for their teaching. Each student teaching session took 20 to 40 minutes of the class time. In the control group, students received the traditional teacher-led instruction.

The CAD modeling exercises assigned to the tutors included modeling features that the students needed to learn. The tutors had one week to learn these features, practice the modeling problems as a group, and design their instruction to teach the tutees in class. For example, the modeling exercise shown in Fig. 1. was to teach students how to use features such as block, pocket, and chamfer in NX. The tutors were encouraged to seek help from the instructor or teaching assistants when they had questions. They searched the Internet and the literature at other times. The preparation for teaching had the potential to help students develop life-long learning skills. During the tutors' teaching sessions, the tutors had full control of the class. The instructor participated in the class as a facilitator only. The tutees listened to the tutors very carefully and followed their directions as shown in Fig. 2. The tutors answered the tutees questions individually and helped them learn.

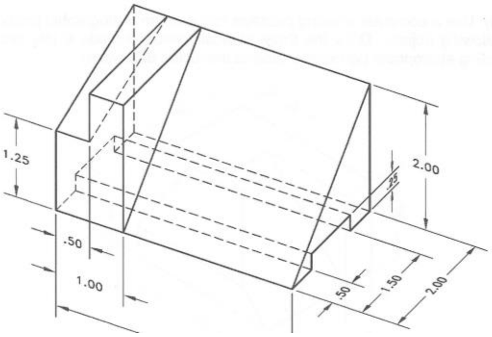

Fig. 1: Example of CAD modeling exercise assigned to tutors.

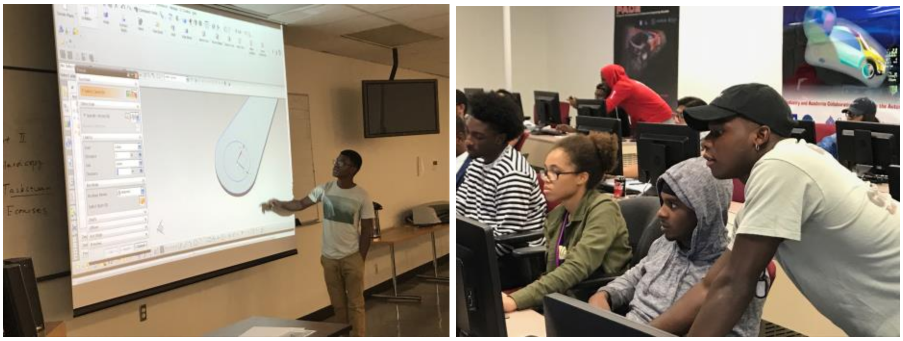

Fig. 2: Students taking teacher's role in class.

In order to evaluate the effect of the project activities on students' learning outcomes and experiences, five instruments were used: a demographic questionnaire, a life-long learning (LLL) scale, an engineering attitude (EA) survey, an exit project survey, and a CAD modeling exam. A questionnaire was designed to capture the students' demographic information including their ethnicity, gender, major, and whether or not they were first-generation-college students in their family. The LLL scale designed by Wielkiewicz & Sinner [5] was used to evaluate the students' life-long learning skills. The LLL scale is a 16-item, 5-point Likert-scale. The EA survey designed by Robinson et al. [4] was used to evaluate the students' attitudes towards engineering, which is a 25-item, 6-point Likert-scale. The LLL scale and EA survey were administered at the beginning and the end of each semester in both experimental and control groups. An exit project survey was designed to explore the students' experiences with the teaching activities. Both open-ended and Likert-type questions were included in the survey. The survey was administrated at the end of semester for the students in the experimental group only. For both control and experiment groups, a CAD modeling exam is given at the end of the semester to assess students' CAD knowledge and ability to use CAD software.

Results and Discussion:

The data accumulated over four semesters since Fall 2015 are discussed in this paper. The analyses of the data collected in Fall 2015 were discussed in Peng et al. [3]. In Fall 2015 and Spring 2016 semesters, each student in the experimental group took the teacher role once. Analyses of the student exit surveys revealed that students preferred to have more than one time to teach in one semester. Therefore, in Fall 2016 and Fall 2017, students in the experimental group were offered to teach two times during the semester. Students who did not complete any one of the research instruments were excluded from the analyses. A total of 140 data samples were collected up to date. There were 40 students in the control group and 100 students in the experimental group.

Life-Long Learning (LLL) Scale and Engineering Attitude (EA) Survey

The students' mean scores in all pre and post surveys were calculated. Each student's gain scores for the life-long learning (LLL) survey and for the engineering attitude (EA) survey were computed by subtracting the pre score from the post score (i.e., gain LLL score = post LLL score – pre LLL score and gain EA score = post EA score – pre EA score). The control group and experimental group are denoted as the subscripts "Cnt" and "Exp," respectively. The standard deviation is denoted as "SD."

The mean scores of the students' responses to the LLL survey are presented in Tab. 1. The results showed that the post LLL scores are higher than pre LLL scores in all groups. T-test results found that post LLL scores of male students ($M_{male\text{-}post}$=3.67) were statistically significantly higher than their pre LLL scores ($M_{male\text{-}pre}$=3.58) (t(113)=2.22, p=0.028) at the $p<0.05$ level. However, Post LLL scores of female students ($M_{female\text{-}post}$=3.72) were not significantly different from their pre LLL scores ($M_{female\text{-}pre}$=3.65) (t(25)=0.94, p=0.36). The post LLL mean scores of students in the control group ($M_{cnt\text{-}post}$=3.75) were not significantly different from their pre LLL mean scores ($M_{cnt\text{-}pre}$=3.65) (t(39)=1.66, p=0.11). Similarly, the post LLL mean scores of students in experimental group ($M_{exp\text{-}post}$=3.65) were not significantly different from their pre LLL mean scores ($M_{exp\text{-}pre}$=3.58) (t(99)=1.82, p=0.07). For the first-generation college students and not-first generation college students, no significant difference was found between their post LLL scores and pre LLL scores. When the gain scores were compared among the different groups (i.e., control group vs. experimental group, male students vs. female students, first generation college students vs. not-first generation college students), no statistically significant difference was found at $p<0.05$ level.

Groups	Number of Students	Pre LLL Score Means (SD)	Post LLL Score Means (SD)	Gain Score for the LLL Scale (SD)
Control Group	40	3.65 (0.56)	3.75 (0.58)	0.10 (0.37)
Experimental Group	100	3.58 (0.51)	3.65 (0.56)	0.07 (0.40)
Male	114	3.58 (0.51)*	3.67 (0.56)*	0.08 (0.39)
Female	26	3.65 (0.62)	3.72 (0.61)	0.07 (0.36)
First generation	44	3.49 (0.49)	3.60 (0.49)	0.10 (0.35)
Not-first generation	96	3.64 (0.54)	3.71 (0.60)	0.07 (0.40)

***Statistically significantly different at p<0.05 level.**

Tab. 1: Mean scores of students' responses to the life-long learning (LLL) scale.

The male and first-generation college students' responses in two types of treatment groups were further analyzed. There were 22 male and first-generation college students in experimental group and 8 male and first-generation college students in control group. T-test results showed that post LLL scores of male and first generation college students in experimental group ($M_{male\text{-}first\ generation\text{-}exp\text{-}post}$=3.49) were statistically significantly higher than their pre LLL scores (($M_{male\text{-}first\ generation\text{-}exp\text{-}pre}$=3.33) (t(21)=2.23, p=0.037). In contrast, post LLL scores of male and first generation college students in control group ($M_{male\text{-}first\ generation\text{-}cnt\text{-}post}$=3.73) were not statistically significantly different from their pre LLL scores ($M_{male\text{-}first\ generation\text{-}cnt\text{-}pre}$=3.55) (t(7)=1.34, p=0.22). This indicates that taking the teacher's role exercises were most impactful for the male and first-generation college students on improving their life-long learning skills.

The mean scores of the students' responses to the EA survey are tabulated in Tab. 2Tab. 2. The results show that the post EA scores are lower than pre EA scores in all groups (i.e., treatment groups, gender groups, first generation college student status). However, t-test results revealed that the decreases of the EA scores are not statistically significant in all groups except the control group and the first-generation college student group. The post EA mean scores of students in the control group ($M_{cnt\text{-}post}$=4.29) were statistically significantly lower that their pre EA mean scores ($M_{cnt\text{-}pre}$=4.48) (t(39)=-2.23, p=0.032). The post EA mean scores of students in first generation college student group ($M_{first\ generation\text{-}post}$=4.24) were statistically significantly lower than their pre EA mean scores ($M_{first\ generation\text{-}pre}$=4.42) (t(43)=-2.43, p=0.019). When the gain scores for the EA survey were compared between different groups (i.e., control group vs. experimental group, male students vs. female students, first generation students vs. not-first generation students), no significant differences were found at p<0.05 level. The findings implied that the teacher-centered instruction has negative impact for students especially for the first-generation college students.

Groups	Number of Students	Pre EA Score Means (SD)	Post EA Score Means (SD)	Gain Score for the EA Survey (SD)
Control Group	40	4.48 (0.47)*	4.29 (0.56)*	-0.19 (0.54)
Experimental Group	100	4.39 (0.43)	4.35 (0.56)	-0.04 (0.49)
Male	114	4.39 (0.43)	4.30 (0.53)	-0.08 (0.49)
Female	26	4.52 (0.48)	4.45 (0.64)	-0.07 (0.56)
First generation	44	4.42 (0.44)*	4.24 (0.57)*	-0.18 (0.49)
Not-first generation	96	4.41 (0.44)	4.38 (0.54)	-0.03 (0.51)

***Statistically significantly different at p<0.05 level.**

Tab. 2: Mean scores of students’ responses to the engineering attitude (EA) survey.

CAD Modeling Exam

Students in both experimental group and control group completed the CAD Modeling Exam. The students’ exam scores in the CAD modeling exam were analyzed among different groups including, different treatments, their gender, and first-generation college status. Tab. 3. lists the mean scores, standard deviations, and t-tests results. In all categories, students in the experimental group performed better than the students in the control group. For example, all experimental group students’ average CAD exam scores (M_{exp}=72.70) was higher than all control group students’ average CAD exam scores (M_{cnt}=67.03) (t=1.17, p=.25). The mean score of male students in experimental group ($M_{male\text{-}exp}$=72.42) was also higher than the male students in control group ($M_{male\text{-}cnt}$=69.35) (t=.57, p=.57). The female students in experimental group scored higher ($M_{female\text{-}exp}$=74.06) than the female students in control group ($M_{female\text{-}cnt}$=59.00) (t=1.36, p=.19). Similarly, when first generation college status was considered, students in experimental group scored higher than students in control group. However, all independent two-sampled t-tests did not reveal statistically significant difference at the p<0.05 level.

Groups	No. of Students	Exam Means	Exam (SD)	t-test	
				t value	p value
Control Group	40	67.03	26.26	-1.17	.25
Experimental Group	100	72.70	24.87		
Male in control	31	69.35	26.16	-.57	.57
Male in experimental	83	72.42	24.44		
Female in control	9	59.00	26.49	-1.36	.19
Female in experimental	17	74.06	27.66		
First generation in control	16	65.75	19.43	-.17	.87
First generation in experimental	28	67.11	28.21		

Not-first generation in control	24	67.88	30.34	-1.03	.31
Not-first generation in experimental	72	74.88	23.30		

Tab. 3: Data analyses of students' CAD modeling exam scores.

Exit Project Survey

Open-ended and Likert-type questions were designed in the exit project survey to capture students' opinions about the learning by teaching activities. One question asked students "*how difficult it was to locate the resources for their teaching role preparation*". While 56 of the students (56%) found it 'not difficult at all', 34 of them (34%) found it 'slightly difficult'. Only eight students (8%) stated that it was 'difficult' to locate the resources for their teaching role. And two of them (2%) choose 'Very difficult'. When students were asked what they "*liked the most in taking the teacher role in class*", students stated how they liked "present their knowledge to the class". They enjoyed "being in charge of their own learning" and developed "a deeper understanding by preparing and teaching other students". Students were also asked what they "*liked the least in taking the teacher role in class*". Some students found it "quite stressful" and "difficult managing the students and keeping their focus on subject matter". As students were asked about "*what they learned new as they prepared for their teaching role and in their teaching experiences*", students stated that they learned "how to solve the problem in several ways" and their "peers provided insight on the easier, more efficient ways to do things". Besides, students also stated that their teaching role helped them to "communicate with others" and "be patient and more open to people". Students were also asked "*how helpful it was to learn the content of the course from their classmates in class*". The results showed that 42 of them (42%) found it 'very helpful' while 45 of them (45%) found 'helpful'. Only 13 of them (13%) responded that it was 'slightly helpful'.

Conclusion:

The learning by teaching method, a student-centered pedagogy, was implemented in a freshman computer-aided design class. The quantitative data and qualitative data were collected and analyzed to examine students' learning of CAD, life-long learning, and engineering attitude. The findings indicated that taking the teacher's role has positively affected the students' life-long learning skills and their CAD modeling knowledge. Among the participants, male and first generation college students have dramatically improved their life-long learning skills. The traditional teacher-centered instruction has negatively and significantly impacted students' engineering attitude. When the Learning by Teaching method was applied, the negative changes in students' engineering attitude were not statistically significant.

Acknowledgments:

This work is supported by US Department of Education Grant No. P120A140064 and the PACE program (Partners for the Advancement of Collaborative Engineering Education).

References:

[1] Bransford, J.; Brown, A. L.; Cocking, R. R.: How People Learn: Brain, Mind, Experience, and School (2nd Edition), National Academy Press, Washington DC, 2000. https://doi.org/10.17226/9853

[2] Carberry, A. R.; Ohland, M. W.: A review of learning-by-teaching for engineering educators, Advances in Engineering Education, 3(2), 2012, 1-17.

[3] Peng, X.; Yuan, T.; Nadeem, U.; Ketsetzi, A.; Yalvac, B.; Eseryel, D.; Eyupoglu, T. F.; Cui, X.: Assigning students teacher's role: a student-centered approach in computer-aided design education, in the Proceedings of the ASME International Mechanical Engineering Congress and Exposition, November 11-17, 2016, Phoenix, AZ. https://doi.org/10.1115/IMECE2016-66871

[4] Robinson, M.; Fadali, M. S.; Carr, J.; Maddux, C.: Engineering principles for high school students, in the Proceedings of the 29th Annual Frontiers in Education Conference, Nov 10-13, 1999, San Juan, Puerto Rico. http://dx.doi.org/10.1109/fie.1999.840333

[5] Wielkiewicz, R. M.; Sinner, A. S.: A life-long learning scale for student development research and evaluation, Personal communication held on August 2010.