Modeling for the 3D Future: CAD Course Redesign to Improve Student Learning

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Abstract

The Computer Aided Three-Dimensional Interactive Application (CATIA) serves as powerful software for aerospace and automotive 3D modeling. We recently redesigned a computer aided design (CAD) class for aerospace engineers to ensure student success and an up-to-date curriculum with applicable industry standards. We refocused the course material to establish relevancy to aerospace engineering as well as promote critical problem-solving skills while constructing parts, assemblies, and drawing sheets in CATIA. The goal of this study is to prepare students for high-level CAD applications by increasing sufficiency and understanding of CAD modeling. We found that after implementation student scores on the timed CATIA certification were significantly higher than with the previous class model indicating that these changes resulted in a better understanding of CAD modeling and formation of expertise.

Introduction

Computer aided design has become a key component for successful design engineers. CAD applications allow engineers to increase design efficiency, accuracy, standardization, and creativity while decreasing labor and time [1]. The way that engineers implement CAD tools greatly affects early designs and can set the course of a project. Both experienced and young engineers need to be equipped with skills in constraint-based computer modeling to keep innovating high level technology and systems [2]. As industries lean further into the world of 3D modeling, students need to learn how to effectively design in computer systems to communicate their visions. Therefore, universities need to keep up with the growing use of CAD and update curriculum to reflect the demands of industry including creative visualization skills, communication, and technical prowess [3].

Experience is widely considered as the path to becoming an expert in any given field [4-6]. In the case of CAD and more specifically modeling in CATIA, beginners start to build their understanding of the program and the basic skills that go into 3D design. As these learners continue to practice, through both failure and success, they slowly develop into experts [4]. The goal of university CAD instruction is to help students build expertise in preparation for advanced work in engineering fields [3].

The CATIA course we studied at a private southwest university was not delivering enough opportunities for students to build expertise. The old course curriculum had been recycled for at least five years meaning at least 10 cycles of students were exposed to the same material with no change, and when the curriculum is reused without change, students reuse the same work as well.

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We believe that student homework submissions were lacking originality resulting in students passing the course without practicing the necessary material to be proficient in CATIA. Poor efficacy and integrity of submitted assignments showed in the elevated fail rates of the Dassault administered CATIA certification exam. To boost exam scores, students needed a higher-level understanding of the tools in CATIA and how to use them effectively and efficiently. The updated course material, which includes completely altered homework and weekly timed quizzes, encouraged student learning and achievement.

Methods

With the goal to raise overall grades and CATIA certification rates, our solution was to change the curriculum at a private southwestern university to give the students more practical experience. While the old curriculum led students through the process of learning all necessary tools to build expertise, it did not have a focus on efficient building, time constraints, or real applications. Additionally, the course is required for all students pursuing a bachelor's degree in aerospace engineering, but the old curriculum lacked relevancy to the aerospace industry. These problems lead to the development of a new aerospace-related and proficiency-based curriculum.

Course Structure: The studied class met three times a week for two hours. The first hour of class was used for instruction, CATIA demonstrations, and general questions. The remainder of class was used for students to work on assignments. Students worked on the assignments both in class and as homework so they could ask questions as well as work through problems on their own.

Curriculum Changes: The new curriculum implemented assignments based on real systems and added weekly timed quizzes to hold students accountable to their learning. These quizzes served to promote time-efficient part building and apply time pressure to familiarize students with conditions of the timed CATIA certification exam. During quizzes, students were instructed to build and submit a screen capture of a part given all necessary dimensions and accuracy is graded based on the student reported mass and volume. For assemblies, students followed the same structure but were graded on the accuracy of the center of gravity. For drafting quizzes, students found the errors or named views and tools on a given completed drawing sheet. This structure was used because it follows the certification exam requirements for masses and volumes of parts, center of gravity for assemblies, and general multiple-choice questions for drafting.

The assignments contain all new material gathered from open-source drawing pages of aerospace parts, engineering manufacturing companies, and adaptations of CAD applications in higher-level university courses. Figure 1 contains a comparison of an old curriculum part (left) with a same-level new curriculum part (right) taken straight from the assignment, respectively. The old part is a junction box with instructor added annotations meant to clear up confusion with the provided, hard-to-see dimensions. Even with the annotations, students were unable match the mass or volume provided in the answer key, which graders use to judge accuracy. The updated curriculum part, a converging diverging nozzle, solves these problems by providing visible dimensions, allowing matchable mass and volume values, and incorporating aerospace concepts. Additionally, faculty A included a lecture on the CATIA certification and its relevancy.

Certification Exam: Students enrolled in the course have the option to take the Dassault administered certification exam without the score influencing their overall course grade. Instructors highly encourage students to take the exam while in university as 1) a certification proves to employers that that person possesses the necessary expertise to perform in CATIA and other CAD applications and 2) the student exam prices are significantly lower than industry exam prices. CATIA offers three different certification exams on part design, assembly design, or surface design. Based on the curriculum in the class, students were prepared and took the part design or assembly design exam.

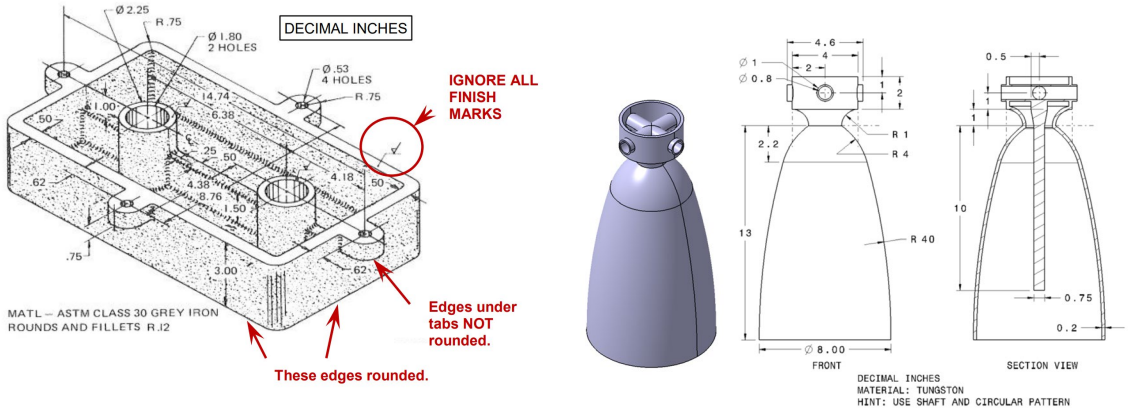

Figure 1: Old (left) and New (right) Curriculum Parts

Participants: We considered data from five sections of a CATIA course. Two sections in spring 2022 were taught by faculty A prior to the new curriculum *(n* = 61*),* two sections in fall 2022 were taught by faculty A after the curriculum was implemented (*n* = 48), and one section in fall 2022 was taught by faculty B who used the old curriculum (*n* = 22). The student population at the private southwest university is primarily undergraduate, traditional students where 27.3% are female and 57% are white. Students range from first semester freshmen to graduating seniors.

Data Collection: For all students in the five sections, we collected their final grade, certification exam score for part or assembly drawing exam, and GPA at the end of the semester (as some of the students were first-year students with no previous GPA). None of the data collected was self-reported. Of the enrolled students, 19 took the exam in spring 2022, 21 from faculty A took it in fall 2022, and 3 from faculty B took it in fall 2022 resulting in 21 students who had the new curriculum (treatment) and 22 who had the old curriculum (control). All 43 students took the part design certification, and 36 took the assembly design certification (15 in spring 2022, 19 in fall 2022 from faculty A, and 2 in fall 2022 from faculty B). The institutional review board determined that the study did not meet the definition of human subject's research and that review was not necessary.

Data Analysis: Data were analyzed in R and compared groups using the Wilcoxon Rank Sum Test (also referred to as the Mann Whitney Wilcoxon Test or the Mann Whitney U test). To ensure we had a large enough sample size, we performed a power analysis using the WMWssp package in R [7].

Results and Discussion

Certification Exam Scores: Comparing the part design CATIA certification scores between the two groups, the treatment group ($M = 75.1$, $SD = 21.8$) had significantly higher scores ($z = 96$, $p < 0.001$) than the control group ($M = 44.1$, $SD = 21.5$). When considering the smaller subset who took the assembly design certification, the treatment group ($M = 78.9$, $SD = 17.2$) had higher trending scores ($z = 100.5$, $p = 0.0870$) than the control group ($M = 64.3$, $SD = 24.8$), but we did not have a large enough sample size for this result. When the two scores were averaged, the treatment group ($M = 76.8$, $SD = 17.5$) still had significantly higher scores ($z = 74.5$, $p < 0.001$) than the control group ($M = 50.9$, $SD = 21.9$). Since a passing grade on the certification exam is 67%, students in the treatment group on average passed the certification exam where the control group on average did not with significantly higher performance on the part design. The relevant practice and updated, non-recycled, problems were clearly successful in helping students develop the expertise needed to pass the exam.

Course Grades: To ensure that the students in the treatment and control groups were similar, we considered if there were any differences between the course grades of the two groups. We found no statistically significant difference between the treatment ($M = 89.2$, $SD = 6.92$) and the control groups *($M = 89.9$, $SD = 6.44$)*. Overall students performed the same in both classes but differently when applying what they learned in the certification exam. The discrepancy in differences between course grade compared to certification exam scores could reflect how long the old curriculum had been reused by students. With the old material in use for at least 5 years without changes, students may have passed down their work for current students to use. Material circulation enables students to practice less, which lowers the efficacy of the course itself.

Grade Point Average: We also considered GPA differences between the treatment and control groups who took the certification exam. The treatment group ($M = 3.65$, $SD = 0.431$) had significantly higher GPAs ($z = 121$, $p = 0.008$) than the students in the control group ($M = 3.29$, $SD = 0.434$). However, a power analysis verified we needed a slightly larger enough sample size (45 instead of 43). To explain this discrepancy in GPAs, we dissolved the treatment and control groups and split all students, regardless of if they took the certification exam, according to the semester that they took the course (spring 2022 $n = 61$, fall 2022 $n = 70$). We discovered that students who took the course in the fall semester ($M = 3.34$, $SD = 0.567$) did not have significantly different GPA than their counterparts in the spring ($M = 3.30$, $SD = 0.577$). Finally, we considered the GPAs of students who elected to take the certification exam ($n = 43$, $M = 3.46$, $SD = 0.464$) with students who did not ($n = 88$, $M = 3.25$, $SD = 0.605$) and saw a trending result ($z = 1501$, $p = 0.0551$) but did not have a large enough sample size for the result. Typically, stronger students elect to take the certification exam because of the cost ($65 per test) whereas those who do not feel as confident in their skills frequently decide not to risk the expenditure.

Conclusion and Future Work

As of now, we can reasonably state that the implementation of the new curriculum had a significant effect on how prepared students are to take the certification exam. The significantly elevated exam scores shows that students are practicing more impactful material and therefore growing their expertise in 3D modeling. Because experience builds expertise [4], the more technically relevant

skills that CATIA students are exposed resulted in elevated degrees of competence and proficiency.

A major reason for the curriculum update was to put a stop to the circulation of assignment answers among students to increase student learning. We plan to continue to update the curriculum by changing the assignment parts to maintain academic integrity as well as continuing weekly timed quizzes to better prepare students for the CATIA certification exam.

We plan to continue to collect data this semester to determine if CATIA certification scores continue to improve. Additionally, another semester of data will help us determine if GPAs are typically higher in the spring or fall semester. Overall, we are excited about this new curriculum change and hope it continues to increase student learning in the future to create expert 3D modelers.

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