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Comparing Exam Scores in Engineering Graphics Courses Using Fully Online Theory Exams vs Exams That Incorporate Hand Sketching

Dr. Nancy E. Study, Pennsylvania State University, Behrend College

Dr. Nancy E. Study is an Associate Teaching Professor in the School of Engineering at Penn State Behrend where she teaches courses in engineering graphics and rapid prototyping, and is the coordinator of the rapid prototyping lab. Her research interests include visualization, haptics, curriculum development, and graphics standards.

Dr. Steven Nozaki, Pennsylvania State University, Behrend College

Ph.D. Engineering Education - The Ohio State University

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Introduction

At Penn State Behrend, an introductory engineering graphics course traditionally had theory exams that incorporated true/false, multiple choice, short answer, and sketching questions. These exams were administered using a paper hard copy during a 50-minute lecture period and were typically closed book and closed note. When the pandemic struck in Spring 2020, by necessity all exams were converted to an online format and administered in Canvas, the LMS used at Penn State. With this change of format, incorporating sketching was difficult, if not impossible, because of the variety of technical capabilities of students away from campus, many of whom did not have the necessary technology or internet bandwidth to scan or photograph sketches and upload them to Canvas.

In the Fall 2020 and Spring 2021 semesters, due to social distancing measures, lectures for this course were still held via Zoom, although labs were in-person. During that academic year, the exams were moved to the lab period from lecture, and all the true/false, multiple choice, and short answer questions were converted fully to Canvas, but the sketching portion was still done by hand during the same exam period. The students were also allowed to use their textbooks during the exam. This same format continued through Spring of 2022.

For the Fall 2022 semester, the exams were converted to an all-online format. They are still taken in person during the lab period under supervised conditions and are open book. The sketching questions have been changed from hand sketching to true/false, or multiple-choice questions. The incorrect answers were created by copying common errors from previous hand-sketched answers.

Course

EGT 120 – Solid Modeling I is a three credit hour introductory engineering graphics course taken primarily by first-semester students enrolled in mechanical and plastics engineering technology majors. There are additional students majoring in an interdisciplinary business with engineering studies program. The course has one 50-minute lecture and two 110-minute labs per week for fifteen weeks. Topics addressed in the course include visualization, sketching, orthographic, isometric, section, and auxiliary views, dimensioning standards, and parametric CAD using Creo. Because hand sketching has been shown to be important to improving visualization abilities and long-term student success not only in engineering graphics but across a variety of engineering courses [1], [2], [3], the first five weeks of the course are spent hand sketching and it is continued throughout the semester even after CAD has been introduced.

Whilst the content in the course is regularly updated to reflect changes in engineering graphics standards and CAD software used, the basic format remained the same for several years. With slight variations in percentage, the paper-based theory exams accounted for around 30% of the course grade, a final CAD project consisting of part models, an assembly, dimensioned detail drawings, and an assembly drawing with BOM around 10% of the grade, practical CAD quizzes

7%, and sketching quizzes 5%. The rest of the grade, around 50% of the total possible points, consisted of classwork, homework, and reading quizzes.

The COVID-19 pandemic brought many changes to the MET courses at Penn State Behrend [4]. In EGT 120, prior to Spring of 2020, theory exams were always administered during the 50-minute lecture period, were on paper, and were not open book. With the closure of campus in the Spring of 2020, and the subsequent requirement of social distancing in the Fall of 2020, and Spring of 2021, the theory exams could not be administered on paper during lectures because even though beginning in the Fall 2020 semester, labs were in-person, the lectures remained remote and synchronous because there was not a room on campus that would hold all the enrolled students and maintain social distancing. Therefore, changes needed to be made in how exams were administered.

Exams

The hard copy exams contained true/false and multiple-choice questions, along with sketching exercises including missing line, missing view, isometric, section, and auxiliary views. The only data available from the hard copy exams prior to Fall 2020 are the overall scores because the hard copies are not kept longer than a year and the sketching portion of the exams was not graded separately. However, these exams were very similar in the types and number of questions to those beginning in Fall 2020. In all of the semesters in this study, there were two exams during the semester, and a final comprehensive exam.

The first exam in Fall 2020, 2021, and 2022 was a 100 point exam with 39 points dedicated solely to sketching. In Fall 2020 and 2021, the sketching was done by hand, and in Fall 2022, the entire exam was on Canvas. Using similar questions to previous exams, the instructors sketched the missing views, added missing lines, and sketched the iso views, and on select sketches deliberately made errors that were common mistakes that students made. Fig. 1 shows two examples of the questions that were in Canvas.

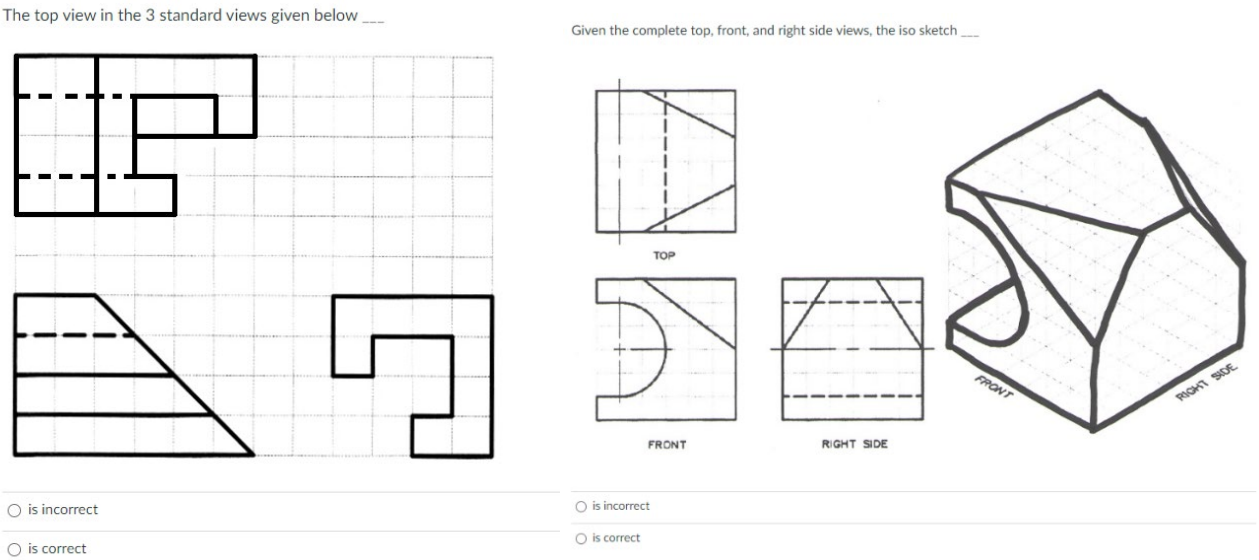

Fig. 1 – sample sketching questions used in Canvas exams

The second exam in Fall 2020, 2021, and 2022 had 30 points out of 100 dedicated to the sketching of auxiliary views, section views, and dimensioning simple multiview drawings. As with the first exam, in Fall 2020 and 2021, the sketching was done by hand, and in Fall 2022, it was all converted to Canvas.

The final exams prior to Fall 2020 were 200 points, contained multiple choice, true/false, and sketching questions, and were always administered in person. In Fall 2020, the exam was converted entirely to an online format because the in-person portion of the semester ended at Thanksgiving break and the last two weeks of the semester, along with final exams, were done remotely. The final exams in Fall 2020, 2021, and 2022 were very similar in content and format, though Fall 2020 was remote with required Zoom attendance with cameras on, and the Fall 2021 and 2022 final exams were in-person. In all final exams, all sketching-related questions were converted to true/false, multiple choice, or matching.

Exam Scores and Analysis

For the first and second theory exams in EGT 120, there are three versions of these exams analyzed in this paper, the traditional paper-based exam, the exam where the true/false and multiple-choice questions were converted to Canvas and sketching was still completed by hand, and the exam that was fully converted to Canvas with the sketching questions converted to multiple choice or multiple answer questions as shown previously. In all versions of the exams, sketching was worth 39 of the 100 total points on the first exam, and 30 of the 100 points on the second exam. When comparing scores on the sketching portions of the exams, hand sketching vs online, only data from exams after the true/false and multiple-choice questions were converted to Canvas is available. Prior to the pandemic, which led to this project, scores on the paper-based exams did not have the sketching scores recorded separately, only overall scores, and hard copies of the exams were not available.

The first question was whether there was a difference between overall mean scores when comparing the completely paper-based exams to the ones where at least part of the exam was administered online using Canvas. There was no significant difference in the scores on either the first or second exam, as shown in Table 1.

Table 1 – Exams 1 and 2 all or partial online vs all paper-based

	N	Mean	SD	p
Exam 1				
All or partial online	111	72.00	10.03	0.53
All paper-based	243	71.17	11.08	
Exam 2				
All or partial online	93	76.81	8.34	0.44
All paper-based	242	75.85	10.28	

The second question regarding the first two theory exams was whether there was a difference in scores on only the sketching section of the exams when comparing the exams that incorporated hand sketching to those where the same or similar sketching questions were converted to an online format. For this comparison, all of the true/false and multiple choice questions were online. Table 2 indicates there was no significant difference between sketching scores.

Table 2 – Exams 1 and 2 sketching only, online vs paper-based

	N	Mean	SD	p
Exam 1 (39 points)				
Online sketching	53	27.46	6.67	0.32
Paper-based sketching	58	26.27	5.87	
Exam 2 (30 points)				
Online sketching	42	20.76	3.66	0.79
Paper-based sketching	51	21.04	4.53	

The 200 point final exams in Fall 2020, 2021, and 2022 were similar in content, all were fully online and open book, the only difference was the Fall 2020 final was administered remotely synchronously, and Fall 2021 and 2022 finals were administered in person. There was no significant difference between the scores on the exams, so they were compared together to scores on previous hard copy final exams that included hand sketching. And as shown in Table 5, there was no significant difference between the scores on the paper-based and fully online final exams.

Table 3 – Final exam fully online vs paper-based

	N	Mean	SD	p
Final exam				
Online	93	157.23	16.78	0.60
Paper-based	215	158.28	16.15	

Conclusion

Prior to the pandemic, instructors at different institutions had been experimenting with switching from entirely face to face instruction in engineering graphics and engineering design courses, to hybrid courses that were conducted partly in person and partly online, including incorporating asynchronous instruction and videos [5], [6], [7], [8]. But there had been little specific discussion of testing or assessing the students' sketching abilities in these hybrid courses. Since sketching and visualization are such an important part of engineering graphics and success in engineering studies, the change from having students sketch as part of their theory exams to choosing correct answers to given sketches was of concern to see if the exam was measuring their sketching knowledge.

One aspect of online exams that was quite positive was the automatic grading of the true/false and multiple-choice questions. Occasionally a single instructor of EGT 120 may have up to 100 students in a semester and grading hard copy exams can take up a significant amount of time. With 60-70% of the exam automatically graded by Canvas, the decision to continue with at least that part of the exam remaining online was made because there was no significant difference in the overall grades on the exams.

The initial results also indicated no significant difference between:

- Online and paper-based theory exams with overall means of 72.00 and 71.17 on the first exams of the semester, and 76.81 and 75.85 on the second exams and p values of 0.53 and 0.44 respectively
- Online and paper-based final exams, with means of 157.23 and 158.28 and a p of 0.60
- Sketching questions online vs paper-based, with p values of 0.32 on the first exam and 0.79 on the second exam

Therefore, the all online exam format will continue for now. More analysis needs to be done on specific questions, including discrimination indices, which are available in Canvas, to more accurately assess whether the online sketching questions are indeed measuring what we intend them to measure.

As noted previously, the first five weeks of the semester in EGT 120 are devoted solely to hand sketching, before introducing CAD work, and the sketching activities continue throughout the semester. Considerable time is spent in class providing formative and summative feedback with these conventional sketching practices. Because of the importance of sketching in developing visualization abilities, even with the success of the format change on exams, there are no plans to replace current lecture and lab sketching activities with items and exercises similar to those being used on exams.

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