Pilot: Extra Credit-Incented Collaborative Learning & Reflection in an Engineering Graphics Course

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Abstract – EGR 120: Graphical Communications students were assigned to peer groups of two members or more per group to complete optional missing line and missing view exercises together outside of regular class time for extra credit such that teammates collaborate to complete problems and visualize solutions. Students also completed self-reflection writing assignments regarding their level of understanding on various engineering graphics concepts at the point in the semester during which the extra credit assignment was given, and answered questions about their meta-knowledge of the topics covered in the course. This assignment has evolved into periodic self-reflection writing assignments benefitting students in that their progress through the curriculum is made apparent both to the students themselves and the instructor, thus serving a formative function as well.

Keywords: engineering graphics, first-year engineering, freshman engineering, spatial visualization, reflection.

Introduction

First-year engineering students take EGR 120: Graphical Communications, part of a set of three fundamental engineering courses required of freshman engineers. EGR 120 is to familiarize the student with the basic principles of drafting, engineering drawing, improve three-dimensional visualization skills, and fundamentals of a CAD program. Students perform free-hand pencil sketching and computer-aided design (CAD) as tools for graphical communication of engineering designs while applying standard view layouts, orthographic projections, section and auxiliary views, dimensioning, tolerancing, and working drawings.

Course Objectives

Specific desired student outcomes state that at the conclusion of the course, students should be able to:

- Identify the character and application of the various lines used in engineering drawings.
- Relate a scaled drawing to actual size and produce drawings to scale and properly use an engineering scale.
- Create neat freehand sketches while adhering to convention and demonstrating the importance of proportions.
- Apply the principles of orthographic projection to construct multiview drawings.
- Apply the principles of isometric projection to create isometric drawings.
- Construct auxiliary views.
- Depict the interior view of an object as a section view.
- Apply the conventions of dimensioning, threads, and tolerancing as necessary in an engineering drawing.
- Interpret, manipulate, and alter a design from a set of working drawings.
- Use CATIA as a computer-aided drafting tool and experience-based judgment to produce two-dimensional orthographic multiviews, three-dimensional isometric pictorials, plus auxiliary and section views, with dimensions and other notations as necessary to fully and clearly communicate a design while incorporating proper engineering drawing formatting and conventions.
- Apply all of the skills gained from above to disassemble, measure, analyze, assess, recreate, redesign, communicate, and document a design via a comprehensive set of working/production drawings.

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In a manner similar to that already described by Sun and Grant [1], students perform exercises in two-dimensional and three-dimensional sketch and computer-aided design with CATIA software through the course of a three credit hour, 14-week semester class that meets twice weekly for two hours per session. The last several weeks of the course primarily focus on less fundamental topics and more so on application of lessons learned towards a project with distinct sets of working drawings, unique to each project team, as deliverables.

VISUALIZATION

Students begin EGR 120 with different levels spatial visualization skills stemming from the range of students' innate gifts and developmental experiences. Student visualization skills can be honed through exercise, as shown by the multitude of studies, particularly those involving pre- and post-instructional testing [2]. In particular, students seem to have trouble with missing line and missing view problems, where standard orthographic multiview projections are missing visible or hidden edge lines (and sometimes center lines), or entire views (of the standard top-front-side view layout, one entire view is missing). These exercises are advantageous for practicing visualization because rather than a fewer number of complete problems which can be time consuming and cause students to spend more time in constructing depictions, missing line and missing view problems allow students to spend less drawing time per problem, thus allowing for a greater number of varied problems and visualization situations. An example of a missing line problem is shown in Figure 1.

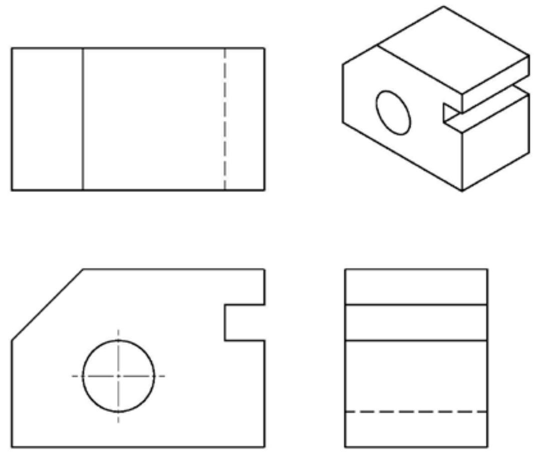

Figure 1. Missing line problem. Students are encouraged to draw the isometric view to help them determine the missing lines in the orthographic views.

FINAL PROJECT

A new project for the Engineering Graphical Communications course (EGR 120) was developed for Fall 2011. The project involves freshman performing a personal product analysis, recreation, documentation, and redesign using computer-aided design (CAD) software (CATIA) in an engineering graphics project. This three-part project involves students choosing a product assembly from their immediate environment to redesign to improve aesthetics and function. In the first phase, students disassemble and measure (using rulers, tape measure, calipers, and/or micrometers, as necessary) the actual parts. In parts 2 and 3 using computer aided tools and CAD they disassemble, reverse engineer, build and document the newly designed and improved object. Most students use calipers and micrometers for the first time as a result of these activities. Students then build the approved product parts in CATIA and accurately assemble and submit via properly formatted working drawings. The redesigned assemblies must improve function, aesthetics, and/or ergonomics and must be properly documented via a formal set of working drawings. Submissions include brainstorming and proposal deliverables, initial product build full working drawings, product redesign full working drawings with attached well-written and properly formatted memorandum describing and referencing product design changes with functional, aesthetic, and/or ergonomic justifications.

The product redesign project is intended to allow for students to tie together many sequentially-presented concepts from throughout the semester into a globally-encompassing project-based learning experience featuring a concrete, familiar context in the form of their personal product selections and informal dissections. The project also requires students to explore additional features within the CAD software that are not specific to the course curriculum. In addition, students are allowed to cycle between the concrete application and examples from their own world to the more abstract and representational world of engineering graphics conventions and CAD modeling. Finally, the project also presents a potential application and context for the skills and concepts internalized by the students. The intention is for students' constant cycling between forms of external and internal representations and the requisite mental transformations of schemata throughout these cycles provides exercises to promote student learning.

The project also presents a series of more realistic and open-ended problems to solve as opposed to traditional engineering graphics assignments. Students working on product redesign project must gather the information they need (measurements, geometry, and assembly constraints from the real world) and apply the best CAD and engineering graphics concepts, conventions and depiction styles (in the standardized representational world) to best complete the modeling and depiction/documentation of their designs, rather than in a traditional early assignment or test question where students are asked to produce a particular type of depiction or demonstrate a particular engineering graphics concept application. Projects that receive a grade of ‘A’ and some ‘B’ projects involve a high level of effort and commitment from students. Visual aids from strong ‘A’ graded project examples are given in Figure 2. These examples represent projects that received a grade of ‘A’ as well as substantial extra credit for the effort invoked and the end product represented.

Figure 2. Exemplary student project representations.

LITERATURE ON REFLECTION IN ENGINEERING DESIGN EDUCATION

The use of reflection in engineering and science education has been a topic of discussion by those exploring the importance of reflection in creativity, as Ghosh cites several real discoveries where in some cases now famous scientists and engineers have reflected on seemingly impossible problems only to spontaneously realize a solution [3]. Formal reflection on active learning tasks in an industry-sponsored project-based learning environment is shown to encourage students to consider their own practices and evaluate best approaches they have encountered [4]. The author was also able to use recorded student reflections in a formative manner, in addition to providing fodder for an informative paper. Reflection driven by mentor questioning can drive student design and design approach improvement [5]. Lawanto [6] suggests that students in ill-defined design projects discuss their problems and approaches early and often with teammates and faculty to avoid misjudging project complexities and avoid adversely impacting their self-efficacy. Students should also engage in a proposal phase that serves to "inventory all tasks and possible methods for the project" (p. 133).

EVOLUTION OF INTERVENTIONS

First-year engineering students enrolled in EGR 120: Graphical Communications were assigned to peer groups of two members or more per group to complete optional missing line and missing view exercises together outside of regular class time for extra credit. Their stated goal was to commit to helping teammates with their ability to complete problems and be able to "see" the correct answers, without simply doing problems for other teammates or copying split portions of the assignment from fellow teammates. Students were also encouraged to consider this extra credit assignment a "trial run" with potential final project teammates. Students of each team signed a team affidavit stating that teammates helped one another visualize without "doing it for them." Bonus points were given only to students who completed the extra problems as part of a team and submitted their work with an attached, signed team affidavit.

Student attitudes about working in groups were gauged via survey responses. The original survey is shown in Figure 3. Student responses are used to inform future full section iterations of this teaching and learning approach in engineering graphics offerings given the summer semester sample size (n=5); however, the evolution of this effort has resulted in a shifted focus towards periodic reflective question and answer on student project efforts, addressing learning outcomes, and student experiences and related learning beyond stated course objectives through collaboration on project tasks. Students also completed self-reflection writing assignments regarding their level of understanding on various engineering graphics concepts at the point in the semester during which the extra credit assignment was given, and answered questions about their meta-knowledge of the topics covered in the course. Reflective writing cues were given orally in lieu of text-based pop quizzes, and sometimes combined with oral versions of questions about the text. This evolution has served to reinforce the student awareness and conscious consideration of the desired outcomes, as well as the significance and relationship of the final project in reinforcing stated desired outcomes and advancing modeling skills and experiences in applying engineering graphics conventions beyond the original boundaries of the stated course learning objectives.

Questions given orally to solicit written and spoken student reflection include:

- What aspects of [the reading topic] do you feel you most/least understand and can apply?
- How is [the reading topic] related to [previous topic] or [stated course desired outcome]?
- What have you learned since [recent previous discussion]?
- Log into [learning management system] and pull up our course desired outcomes. What can you do that addresses these outcomes? What can you not do or do not feel so comfortable or confident doing?
- Do you enjoy working together in the classroom? Do you enjoy collaborating on assignments? What aspects do you or don't you appreciate about working together to accomplish class objectives?
- What do you anticipate being the most difficult aspects of the project?
- What aspects of your product will present the greatest modeling challenge? What ideas do you have to approach modeling these features?
- Is the time provided to [complete any assigned task, typically a longer assignment] adequate?
- Did you find [specific quiz or test] too easy, too difficult, or fair? Was there enough time allocated?

EGR 120 **Name (optional):________________________**

Collaborative/Independent Learning Survey

Please circle or highlight the appropriate number on the 5-point scale representing your feelings for each corresponding statement below, where 1="Never" and 5="Always"

1. I frequently worked with other students to solve problems in class.	1	2	3	4	5
2. I frequently worked with other students to complete class projects or assignments.	1	2	3	4	5
3. Working independently from other students had a positive influence on my learning.	1	2	3	4	5
4. I like to work in groups in this class.	1	2	3	4	5
5. I ask questions of others when I work in a group.	1	2	3	4	5
6. I understand the class concepts when I work in a group.	1	2	3	4	5
7. Others in the group ask me questions when we work in groups.	1	2	3	4	5
8. Working in a group helps me understand the concepts better.	1	2	3	4	5
9. Working in a group helps me get the work completed on time.	1	2	3	4	5

Please answer the following questions.

10. Did you complete the class project INDEPENDENTLY or as a GROUP?
(circle or highlight one)

    Regardless of your answer, what did you like and dislike about working on the class project in this manner? Please type your answer below. There is no space limit.

11. Did you complete the missing lines / missing views extra credit group assignment?
YES or NO? (circle or highlight one)

    If you answered YES, in what ways did you find the extra credit group assignment helpful or not helpful? Please type your answer below. There is no space limit.

12. In general, why do/don't you like to work in groups?
Please type your answer below. There is no space limit.

Figure 3. Collaborative/independent learning survey.

- What would you change or recommend changing for future iterations of this course?
- What would you change about the project?
- If you could go back and redo something like your approach or similar in this class, what would it be?
- If you could change something about you project or project topic, what would it be?
- How has the project helped you address the course objectives?
- How has the project helped you advance beyond the stated objectives of the course?

- What, if anything, surprised you most about this course?
- What did you find surprising about the project?
- Have you kept your product with you and used it as often as possible to determine design shortcomings (or additional desired functions, enhanced ergonomics and/or aesthetics) that you would like to address in your product redesign? What are they?
- Describe the non-standard views (other than standard orthographic and isometric views) and documentation steps for your working drawings to properly and fully communicate the design of your product.
- How many unique parts, standard parts, and total parts will your project entail?
- How many parts do you anticipate will be affected by your initial proposed design changes?

THEMES IN STUDENT FEEDBACK

The original collaborative extra credit missing line and missing view assignment has encouraged the instructor to promote periodic self-reflection discussion and impromptu writing assignments which seem beneficial to students as their progress through the curriculum is made apparent both to the students themselves and the instructor (thus serving a formative function as well). Both the student attitudes survey and open-ended reflective pop quizzes have encouraged instructor reflection on curriculum, style, and teaching and learning environment.

Another outcome of the extra-credit team assignment and self-reflection papers is the quality of participation and work submitted for group projects, which are demanding. Students are given an opportunity to work with others in the class before committing to the team project, and the periodic self-reflection assignments allowed students to pause and think more deeply about how they are approaching their project solutions. Pop quiz reflection responses asked students to think about their meta-knowledge compared against stated course desired outcomes. Full-section iterations (n=52) are ongoing with the impromptu reflective pop quizzes and seem to reflect similar feedback from students regarding meeting course objectives and learning about new features in engineering graphics and computer-aided design software package CATIA, as well as approaches that are transferrable to other packages. Students from both the summer and fall semester sections indicate that the project reinforces many aspects of the classroom initially covered through isolated, focused daily assignments sequenced by topic. Students state that, and relevant to the literature [6], the project is generally a lot of work and a greater commitment with more demands for new modeling approaches than they had anticipated. Students also noted that documentation conventions are applied in a manner atypical of simpler, more abstract daily assignment problems encountered earlier in the semester, but that demands on their judgment for properly documenting and annotating irregular geometries was very beneficial to their learning.

Although a major time and effort commitment for the students, students always concede that the project helps them develop their skills and reinforces engineering graphics concepts and conventions better than any other assignment or activity in the course. Students also state that their work on the project allows them to learn about features and tools in the CAD (CATIA) package of which they were not previously aware or did not have the opportunity to explore. Students also say that the project is “fun” and interesting compared to their traditional assignments. Furthermore, students indicate they tend to feel like they are given an opportunity to see all the course topic areas as part of a “big picture” rather than just segregated, individual concepts. More post-project student thoughts and reflections will be comprehensively captured in a final project and course reflection assignment at the end of subsequent semesters.

MOVING FORWARD

Challenges exist in ensuring that team members equitably contribute on their respective teams, although this only seems to be an issue on a few teams. Most students enjoy collaborating; however a significant minority of students does not enjoy collaborating, typically citing unfair division of labor, disorganization and scheduling, and a desire to perform all tasks to a personal standard. Both as professionals and throughout their academic careers, students will generally be expected to perform well and maintain good team dynamics when they work collaboratively; however there is also an expense of stifling student preferred learning styles when mandating teamwork. It is also a challenge to get students to truly collaborate synergistically rather than just sum the parts of their efforts after completely segregated work sessions. Some students insist on working alone, and occasional exceptions are made, though discouraged. Although reflection should not be mistaken for a panacea, more reflection on collaboration and team dynamics can be solicited to help address some of these issues, as well as team building exercises beyond the collaborative missing line / missing view bonus assignment. Allocating more classroom time can also help address team synergy.

An opportunity also exists to show student engineering graphics gains immediately before and after project participation due to a reduced amount of new material introduced once the project commences. For research purposes, if the project were completely segregated from new material (a tall order), instruments could be introduced as pre- and post-project checks to gauge student aptitude in engineering graphics and computer-aided design topics to determine the impacts of the project experience on students.

CONCLUSION

A narrative was presented where one intended instructional intervention evolved to meet the conditions of the classroom environment. This development turned out to be beneficial to student and instructor reflection and affected student and instructor actions to meet course educational objectives. Opportunities to improve student collaboration, promote dialog to encourage student preparedness at earlier stages of the final project, and to give students more time to consider project tasks and solution directions continue to drive the refinement and formalization of reflection the EGR 120 classroom.

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