Modifying an Assembly Project to Improve Student Dimensioning Skills

Ms. Norma L Veurink, Michigan Technological University

Norma L. Veurink is a Senior Lecturer in the Engineering Fundamentals Department at Michigan Technological University where she teaches introductory engineering courses and a spatial visualization course designed for engineering students with poor spatial visualization skills. Ms. Veurink manages several summer programs that introduce middle and high school students to engineering. She is the Secretary/Treasurer for the Engineering Design Graphics Division of ASEE and is also a member of the American Society of Civil Engineers and an advisor for Tau Beta Pi. Her research interests include spatial visualization, engineering education, and first-year programs.

Dr. Gretchen L. Hein, Michigan Technological University

Gretchen Hein is a senior lecturer in Engineering Fundamentals at Michigan Technological University. Her focus is on how students learn and how to make classes more interesting and applicable to the students. She currently teaches first-year engineering courses along with an introductory course in thermodynamics and fluid mechanics.

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Abstract

Many first year graphics courses introduce students to solid modeling and technical graphics. At Michigan Technological University, all engineering students take a two to three semester sequence of introductory engineering courses. The last course in the sequence, ENG1102: Engineering Modeling and Design, focuses on solid modeling (3-D CAD), graphical communication, and computer programming. The solid modeling portion of the class exposes the students to sketch-based and feature-based solid modeling and creating engineering drawings and assemblies. The graphical communication portion of the course includes dimensioning, section views, and view selection. To give the students practice in creating CAD assemblies using parts they modeled themselves, student teams complete a project where they either model an object which consists of a few simple components or design an object using simple components such as PVC pipe. Students are given the components of the assembly and calipers to measure them during at least two class periods and are allowed to collect additional measurements at various times outside of class time. The students submit engineering drawings of the fully dimensioned components in the assembly and the part assembly.

In the fall of 2012, the assembly project was modified in one section of ENG1102 in an effort to improve students' dimensioning skills. In this experimental section, the students were given a spring scale to dissect, measure, sketch, and dimension by hand in a single 75-minute class period. The students created solid models of the components from their sketches, and if necessary dimensions were missing from their initial sketches, they submitted a formal request to the instructor to obtain them. In the two control sections of the course, the students were given the same spring scales to model and measure in two 75-minute class periods. Additionally, if dimensions were needed outside of class, they had easy access to the scales. Individuals from each student team in both the control and experimental sections submitted fully dimensioned engineering drawings of two components of the spring scale.

In order to assess if the change in the project did improve students' dimensioning skills, students were asked to complete a survey regarding the project. Responses to the survey and exam questions on dimensioning were compared. This paper will discuss the findings from these analyses.

Background

Most engineers will create a drawing at some point in their career. For the object to be created, the material, structure and size need to be documented. Traditionally, students have learned how to do this in a "drawing" course. In these courses, students learn how to construct a multi-view drawing, a schematic or a diagram to illustrate the components of their design. Additionally, they add notes and dimensions to describe the materials and size of the object.

Most of the time dimensioning is taught based on the modeling package or the textbook being utilized. There are two typical methods of dimensioning. One is based on a universal standard, like ASME Y14.5-2009, where the rules for dimensioning parts and tolerances are outlined for students and practitioners. This method is primarily used when specifying a specific manufactured part and is not used in the construction industry.[1] In the construction industry, dimensioning emphasizes the structural features of the object and typically, tolerancing is not used.[2] For both methods, the overall size of the object, along with the size and location of individual features, are important.

Universities teach dimensioning of drawings in different courses and with various coverage. In manufacturing engineering programs, students typically learn dimensioning over a course of several courses. At Southwest Texas State University, dimensioning is explicitly covered in two technical classes. This knowledge is applied in additional upper division courses where students create parts and must dimension them such that they can be built. Therefore, the concepts are reviewed and applied in additional courses.[3] In a semester-long course at Mercer University School of Engineering, students utilize pencil drawings and progress to computer-aided drawing (CAD) and solid modeling. The purpose is for students to learn the basics of dimensioning and drawing before using an electronic method. Then when they create a CAD drawing they can draw on their experience of hand drawing to create the object and dimension it. The hand drawing and CAD skills are further developed when they begin to learn solid modeling.[4] Other institutions have elected to teach dimensioning and drawing in a totally electronic format.

Engineering students learn the basics of dimensioning in the first-year engineering program at Michigan Tech. At Michigan Tech, there are several engineering majors: mechanical, civil, environmental, biomedical, geological, electrical, computer, and materials. The majors using the ASME type approach are: mechanical, biomedical and some materials, electrical and computer engineering students. The latter three majors would need dimensioning skills when the component they are designing or constructing must fit in a certain region or cannot exceed a certain size. The structural type of dimensioning is found more often in the civil engineering field, but also in chemical, environmental and geological engineering. Chemical and environmental engineers design process facilities ranging from refineries to water treatment plants. Geological engineers who focus on either reservoir development or mining operations need to dimension the structures involved in their processes or the geo-strata being impacted by their operations. Therefore, the knowledge of how to dimension an object is needed for all engineering majors at Michigan Tech.

Dimensioning engineering parts or designs is a difficult topic for engineering students to learn especially when they do not have a class dedicated to drafting. At Michigan Tech, dimensioning is covered in about two lectures. This means that students need to learn the nuances and rules of dimensioning complex parts in a very short period of time. As shown in the text above, most students spend at least one or more semesters learning dimensioning where at Michigan Tech, students have a very limited exposure. Therefore, creative and innovative methods have been developed to assist students in learning this complex topic. One of the more recent developments is described below.

Description of the Study

At Michigan Tech, dimensioning is taught in Eng1102: Engineering Modeling and Design, a course taken by all engineering majors. The course covers solid modeling with Siemens NX, dimensioning, sketching of oblique surfaces and section views, and computer programming with MATLAB. Engineering freshmen who enter the university ready to take Calculus I or higher typically take this course their second semester. For students entering Michigan Tech who are not Calculus ready, this is the third of a three-semester sequence of introductory engineering courses, and they typically take the course in the fall semester of their second year. Other students taking the course in the fall semester are students who transferred from other colleges and universities, students who failed one or more of the introductory courses the prior year, and students who transferred into engineering from other curriculums. This paper focuses on a study of dimensioning skills that was performed in the fall 2012 semester.

Dimensioning is typically taught over two class periods. Prior to the first class period where dimensioning is discussed, students watch a 12 minute video and complete an online quiz covering the guidelines mentioned in the video. The video covers dimensioning placement guidelines, compares chaining versus baseline dimensioning methods, and explains the avoidance of redundant dimensions. During the first class period, radial, angular, and cylindrical dimensions are introduced. The students are given a general dimensioning procedure and reminded that all necessary dimensions need to be shown, but no more dimensions than those necessary should be given. Two example objects are dimensioned with the instructor leading the dimensioning exercise and reviewing the placement guidelines as they apply to the objects being dimensioned. Students then dimension three simple objects while the course instructor and teaching assistant provide assistance to individuals as needed. Students submit these three problems at the end of the class period. The instructor uses previous years' submissions as examples of student work and leads the class in critiquing them the second session. The objects are critiqued relative to style, placement, completeness, and necessity of dimensions. Following the critique of the objects, students dimension three additional objects which contain more detail than the first day and are shown the correct way to dimension the objects at the end of the exercise. Approximately 2 to 2.5 hours are spent in class on instruction and dimensioning exercises. Over the course of the next several weeks, three homework assignments and an additional in-class exercise require students to completely dimension a variety of objects. The first homework assignment requires the students to dimension several objects by hand, while the other two homework assignments and an in-class activity focus on learning the drafting application of NX while applying the dimensioning skills learned earlier. The NX-related dimensioning assignments and exercises require students to submit completely dimensioned engineering drawings of a part.

One of the homework assignments requiring students to submit a completely dimensioned engineering drawing of an object is the first component of a larger assembly project. In this project, students work in teams to model and assemble a physical object in NX. The purpose of the project is primarily to give students practice in creating solid models of components which need to be used in an assembly. This helps students gain an understanding of the importance of communication with team members as they model the components. In the fall of 2012, this exercise was modified in one of three sections taught by the instructor. Before the project was introduced, the instructor polled the students to see how many of the students had taken a drafting class in high school. In one section, 26% of the students said they had taken a drafting class in high school, 35% of the students said they did in another section, and 47% had in the third section. Based on this response, the section where 35% of the students reported taking a drafting class in high school was chosen as the section to complete a modified form of the project.

In two of the sections, the control group, students were given a spring scale to measure, sketch if desired, and model in NX in two 75 minute class periods. Students were also told they could come to the instructor's office as needed to get additional measurements. In the experimental section, students were given a spring scale to measure and sketch in one 75 minute class period and were instructed to make the solid models from the completely dimensioned sketches. Students were told they would only have the one class period to gather the necessary dimensions. Students in the experimental section were made aware that this method (restricting the students to model the object from their sketches) was different than how the project was completed in the past.

The spring scale contained ten parts: four red plastic pieces, two metal hooks, a white plastic nut, a clear plastic tube, and two springs. Each student submitted engineering drawings of two of the parts. Because some of the parts were much simpler to model than others and because some of the student teams contained three members while others had four members, each student was to model and create an engineering drawing of one of the red pieces of the scale.

To determine if the exercise of having students sketch and completely dimension an actual object and then produce a solid model from that sketch improved dimensioning skills, several measures were compared. Student performance on exam dimensioning questions and responses to a survey about the spring scale project were compared between the experimental and control groups. Class composition by major was also compared as some engineering majors may perceive dimensioning skills to be more critical for their discipline than other disciplines and thus may put forth more effort on the dimensioning exercises.

The distribution of majors in the experimental and control groups are compared in Table 1 below. The majors are grouped by perceived need for dimensioning skills. Proper dimensioning is critical in the mechanical, civil and biomedical engineering fields, and it is assumed students in these disciplines recognize this. Chemical, environmental, and geological engineers may have less need for good dimensioning skills depending on the career path they choose, so these students may not perceive as strong a need to master the dimensioning concepts. Electrical, computer, and materials science and engineering students likely feel dimensioning is the least critical to their discipline and thus may put forth less effort than the other engineering groups. As can be seen from the table below, the experimental group had a 17% lower percentage than the control group of students to whom dimensioning is perceived to be the most critical. Additionally, there were 10% more students from the majors where the perception of the need of these skills may be the lowest.

Table 1: Study participants by major

	Experimental Group n=52	Control Group n=103
Mechanical, Civil and Biomedical Engineering	46% n=24	63% n=65
Chemical, Environmental, Geological	19% n=10	13.5% n=14
Electrical, Computer, and Materials Science	23% n=12	12.5% n=13
Engineering Undecided	8% n=4	8% n=8
Other	4% n=2	2% n=3
Total	100%	100%

Results of the study

For the spring scale assignment, each student was to model and submit fully dimensioned engineering drawings of one of the four red plastic parts of the spring scale. This was so that each student modeled and dimensioned a part of comparable complexity. Besides the red plastic parts, the other parts of the spring scale included a hex nut, a simple tube, and two wire hooks which students in the control group could easily have traced rather than recording the necessary dimensions before modeling the part. The drawings of the red plastic parts were analyzed for missing and redundant dimensions. During this analysis, it was noticed that student models of one the red parts varied significantly, so the dimensioned drawings of that part were excluded from the analysis. Some students did not submit drawings or did not submit drawings of the correct part, so the number of drawings examined was lower than the number of students in the control and experimental groups. Table 2 below shows the result of this analysis. Students in the experimental group missed more necessary dimensions than did the control group, but had fewer redundant dimensions than the control group. Ten to twelve dimensions were required to fully describe the parts, so the number of missing dimensions was significant for both groups. It should also be noted that two of the parts analyzed below consisted of cylindrical endcaps with holes, slots, grooves, pads, and two different sized cylindrical surfaces.

Table 2: Missing and redundant dimensions on spring scale part

	Experimental Group n=35	Control Group n=66
Average number of missing dimensions	2.4	1.77
Average number of redundant dimensions	0.63	0.85

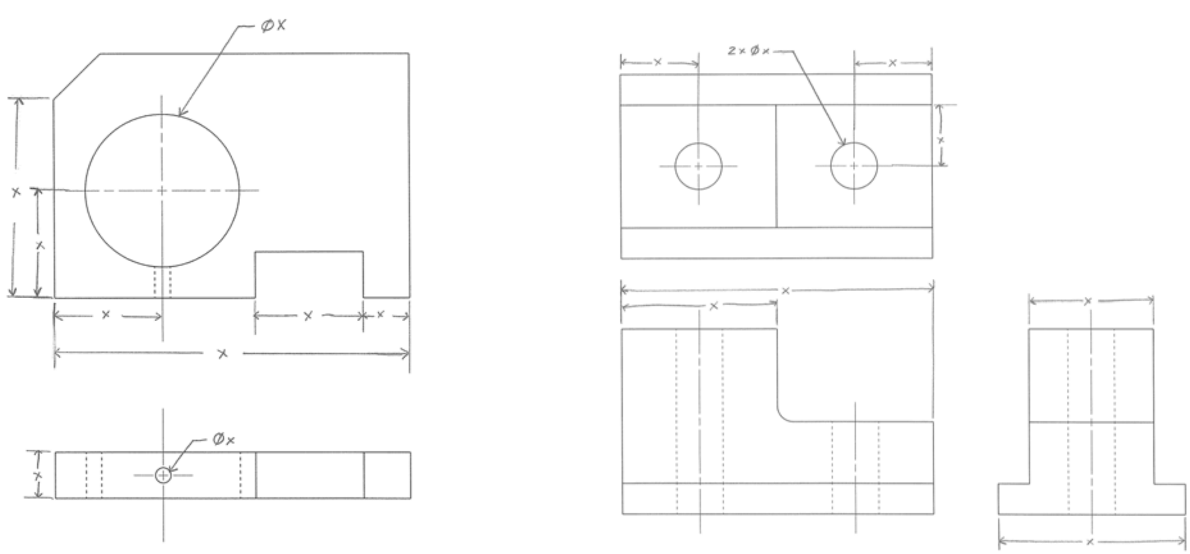
The midterm exam in the course occurred in the eighth week (out of fourteen weeks) of the semester and covered solid modeling in NX, sketching section views and oblique surfaces, and dimensioning. One question on the exam asked the students to completely dimension an object when given two of its orthographic views. A total of eleven dimensions were required to completely dimension the exam object. The number of missing and redundant dimensions on the object was compared for the two groups. Table 3 below shows both groups on average missed placing less than two of the eleven required dimensions on the object. The experimental group missed an average of 0.25 more of the required dimensions than the control group. Both groups had about the same average number of redundant dimensions.

Table 3: Missing and redundant dimensions on midterm exam by group

	Experimental Group n=51	Control Group n=103
Average number of missing dimensions	1.73	1.49
Average number of redundant dimensions	0.51	0.54

To provide an assessment of the students' retention of the dimensioning skills, the final exam included several multiple choice questions regarding dimension placement rules and two questions related to how many dimensions were required to completely dimension an object. For these two questions, a partially dimensioned object was given, and students were asked in a multiple choice format how many dimensions needed to be added to completely dimension the objects.

In the class, students are required to dimension objects completely, such that no assumptions need to be made by someone who is fabricating the object. This means that even though an object appears to be symmetrical, sufficient dimensions must be placed on the object to fully define the object without having to make this assumption. The first object on the exam included a hole that was obviously centered from top to bottom on the part. Thirteen dimensions were required to completely describe the object, and nine dimensions were placed on the partially dimensioned object. The second object was symmetrical and included a raised rectangular surface centered on a rectangular base. The object also had a small edge blend. Thirteen dimensions were required to completely describe the second object, and eight dimensions were placed on the partially dimensioned object. The two exam objects are shown in Figure 1 below.



Object 1

Object 2

Figure 1: Partially dimensioned objects on final exam.

Table 4 below compares the success of students in the two groups on these questions. The percent of students correctly identifying the number of missing dimensions was approximately the same for both the control and experimental groups. However, about 10% more of the students in the experimental group identified the number of missing dimensions as one less than the correct number. A lower percentage of students in the experimental group selected an answer that reflected more than the number of missing necessary dimensions than students in the control group.

Table 4: Identification of missing dimensions on the final exam by group

	Experimental Group n=51	Control Group n=98
Correctly identified the number of missing dimensions on object one (Selected four missing dimensions as their answer.)	15.7% n=8	18.4% n=18
Identified the number of missing dimensions on object one as one less than those necessary (Selected three missing dimensions as their answer.)	39.2% n=20	29.6% n=29
Correctly identified the number of missing dimensions on object two (Selected five missing dimensions as their answer.)	27.5% n=14	25.5% n=25
Identified the number of missing dimensions on object two as one less than those necessary (Selected four missing dimensions as their answer.)	23.5% n=12	14.3% n=14
Identified the number of missing dimensions on object one as more than those necessary	5.9% n=3	5.1% n=5
Identified the number of missing dimensions on object two as more than those necessary	7.8% n=4	15.3% n=15

At the completion of the spring scale assembly project, students were asked to complete an on-line survey regarding the project. The questions on the survey and possible responses are shown in Table 5. So that a consistent comparison could be made, several of the questions referred specifically to the red parts of the spring scale. Responses were correlated to 5-point scale which is also shown on Table 5. The intent of the survey was to determine how well the students gathered the necessary dimensions of their part, the time required to model and dimension the part, and the students' overall rating of the assignment.

Table 5: Survey questions and possible responses regarding spring scale assembly project

Rating	1	2	3	4	5
How much drafting/drawing experience did you have prior to this class?	More than four semesters	Three to four semesters	Two semesters	One semester	None
How many dimensions from the red part you modeled did you get from a classmate in the same or another section of Eng1102?	More than 5	4-5	2-3	1	0
How many dimensions for the red part you modeled did you get from the learning center?	More than 5	4-5	2-3	1	0
For the red part you modeled, how long did it take you to model the part?	120 or more minutes	90 minutes	60 minutes	30 minutes	15 minutes
For the red part you modeled, how long did it take you to fully dimension the engineering drawing of the part?	60 or more minutes	45 minutes	30 minutes	20 minutes	10 minutes
How would you rate this assignment with respect to your dimensioning skills?	This exercise provided no benefit to my skills	This was not a learning exercise, but provided good practice for my skills	I learned little during the completion of this assignment	I learned some during the completion of this assignment	I learned a lot during the completion of this assignment
How would you rate this assignment with respect to your NX assembly skills?	This exercise provided no benefit to my skills	This was not a learning exercise, but provided good practice for my skills	I learned little during the completion of this assignment	I learned some during the completion of this assignment	I learned a lot during the completion of this assignment
How would you rate this assignment overall?	Very Poor	Poor	Fair	Good	Excellent
I recommend this project be completed in future Eng1102 classes.	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree

Table 6 summarizes the survey responses of the two groups. The students in the experimental group had slightly less prior drafting experience than students in the control group. The questions concerning getting dimensions from another classmate or from the learning center were asked to ascertain if students in the experimental group were largely able to model their objects in NX from their hand drawings or if they found they missed dimensioning features of their objects. Students in the control group had two class periods in which to model their objects and collect necessary dimensions, but due to the fact the students worked in teams of three or four and there were only two computers available per team, not all students in the control group were able to model their parts in the two class periods. They were told the second class period to collect whatever dimensions they needed as no more class time would be spent on the project and it would be easiest to get all needed dimensions by the end of class. From the survey responses, it appeared both the experimental and control groups missed collecting needed dimensions during their allotted class periods at about the same rate. A few of the students in the control group did come to the instructor's office to collect additional dimensions; so the control group did miss needed dimensions at a slightly higher rate than the experimental group. The students in the experimental group were able to model their red part in NX slightly quicker than the control group, but both groups took about the same amount of time to completely dimension the engineering drawing of their red part.

Table 6: Assembly project survey results by group

	Experimental Group n=44	Control Group n=92
How much drafting/drawing experience did you have prior to this class?	3.39	3.26
How many dimensions from the part you modeled did you get from a classmate in the same or another section of Eng1102?	4.59	4.58
How many dimensions for the part you modeled did you get from the learning center?	4.91	4.89
For the part you modeled, how long did it take you to model the part?	3.95	3.79
For the part you modeled, how long did it take you to fully dimension the engineering drawing of the part?	4.27	4.24
How would you rate this assignment with respect to your dimensioning skills?	3.45	3.18
How would you rate this assignment with respect to your NX assembly skills?	3.78	3.45
How would you rate this assignment overall?	3.61	3.35
I recommend this project be completed in future Eng1102 classes.	4.09	3.53

Overall, the students in the experimental group had a more positive outlook on the project than students in the control group. They found the project to be more beneficial to their dimensioning and NX assembly skills. They rated the overall assignment higher than the control group. More students in the experimental group strongly recommended this project be completed in future course offerings. In addition to the questions on the survey shown above, students were asked to choose the most accurate description of how they felt about the project. Table 7 below shows the experimental group found the project to be less challenging, less frustrating, but more interesting than the control group. The students in the experimental group, but not the control group, were told the project was being conducted in a different manner to determine if the new method resulted in better dimensioning skills. This may have impacted their overall attitude toward the project.

Table 7: Student feelings regarding assembly project by group

Overall I found this project to be:	Challenging	Enjoyable	Interesting	Unremarkable	Frustrating
Experimental group response	18.2% n=8	15.9% n=7	45.5% n=20	6.8% n=3	13.6% n=6
Control group response	23.9% n=22	15.2% n=14	33.7% n=31	9.8% n=9	17.4% n=16

Conclusion

The results of this study are not definitive, but suggest the method of having students sketch and record all necessary dimensions of an object and then creating a solid model and fully dimensioned engineering drawing from the sketch may not be effective. Students in the experimental group under-dimensioned the drawing they created using this method and under-dimensioned an object on the midterm exam at a higher rate than those in the control group. However, on the final exam, the experimental group outperformed the control group in determining how many dimensions were missing from a partially dimensioned object. This suggests the project may have increased the long-term retention of dimensioning skills of the experimental group. Overall, the experimental group had a more positive outlook on the assembly project, however, this may have partly been due to the fact that they knew something different was being tried in order to improve their dimensioning skills. A follow-up study where both the experimental and control groups are told the project is being conducted in a different manner to determine if doing it in this manner improves their dimensioning skills would remove this possible bias. Repeating this study by having students measure and then model objects with few curved surfaces may also prove to be more definitive as the spring scale components in the assembly project had several curved surfaces. It is likely more difficult for novices to properly dimension multiple curved features in comparison to dimensioning multiple linear features of an object.

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