

AC 1999-51: Dimensioning Through Understanding Geometry

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Abstract

Dimensioning practices and standards are usually taught in introductory courses in Engineering Graphics. Knowledge of these practices is valuable to graphics students. It is also essential that students learn to dimension a drawing completely so it will describe its geometry and avoid *missing* dimensions. A teaching method to instruct dimensioning practices in Engineering Graphics is discussed in this paper. The "*Simple Geometry Method (SGM)*" involves an understanding of a drawing by process of simplification. A drawing (complex geometry) is created from several simple geometries such as lines and circles. Therefore, it is important that students identify these simple geometries and provide dimensions for them. By following the SGM students will notice all required dimensions to describe the complex geometry. Preliminary data analysis showed that SGM significantly improved the students understanding and learning of dimensioning practices to *avoid missing dimensions*.

I. Introduction

Students in introductory graphics courses typically study the standard practices of dimensioning that includes types of dimensioning; current standards; symbology; units and etc. Although these factors are important, the value of complete dimensioning in order to describe the geometry of an object is often undermined. By failing to understand this, dimensioning by students results in missing dimensions. A complex geometry is created from several simple geometries. If students can recognize these simple geometries and can provide dimensions for them, they will not miss any required dimensions.

The objective of this paper is to: 1) introduce a teaching method to avoid missing dimensions in a drawing, and 2) present results from classroom trials of this teaching method.

Classroom trials were performed to insure the validity of this approach. Two institutions, a four-year college and a high school, took part in the study. The studies involved pre-tests and post-tests to evaluate students performances before and after learning SGM.

II. Method

Nearly all geometric shapes, such as arcs, polygons, ellipses can be described in terms of lines and circles (Figure 1a. and Figure 1b.). Therefore, a complex geometry can be identified as the combination of several simple geometric shapes¹. Lines and circles are the best to illustrate a complex geometry. Once students recognize the composition of geometry in terms of lines and circles, they only need to provide the dimensions of these. Also, students will recognize types of circles (concentric, eccentric, etc) and types of lines (intersecting, tangent,

perpendicular, etc.). Students will realize that while radial dimensions *and* relative locations for the circles are essential, not all lines require linear dimensions. Providing linear dimensions for lines will depend on types of lines.

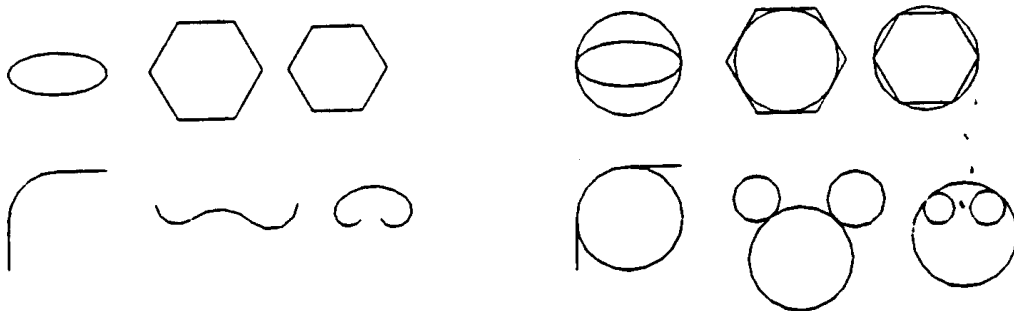


Figure 1a. Example of geometric shapes Figure 1b. Geometric shapes of Figure 1a. in terms of lines and circles

This method, "***Simple Geometry Method (SGM)***" has four steps that simplify a complex geometry for complete dimensioning. The steps are, 1) identifying all circles and lines including types of lines and types of circles, 2) providing radial dimensions for all circles, 3) providing linear dimensions to center of these circles, relative to each other, 4) providing linear dimensions for lines which are not tangent to circles.

Example

A complex geometry is shown in Figure 2a. The same geometry is composed of several simple geometric shapes, mostly lines and circles (Figure 2b.). In order to describe the complete geometry of Figure 2a, eight radial dimensions are needed because eight circles (C1- C8) are present. It is to be noted that the polygon (P1) is also defined in terms of radial dimension of the circle on which it is circumscribed. In addition, three linear dimensions are required to locate the centers of these circles. Linear dimensions are not required for two lines (L1, L2), because these lines are tangent to circles at both ends. Therefore a total of eleven dimensions are *required* to describe the geometry of Figure 2a.

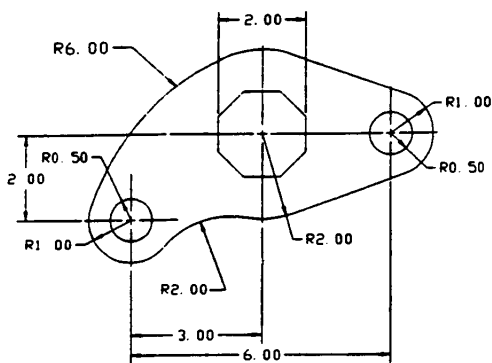


Figure 2a. An example of complex geometry

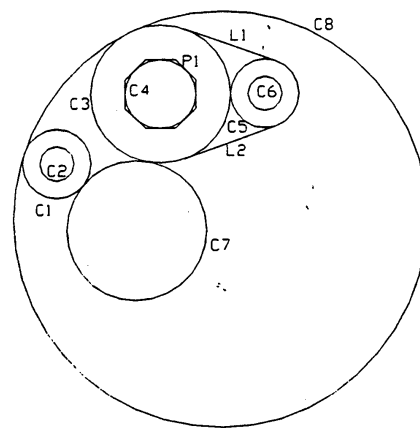


Figure 2b. Drawing shown in Figure 2a, in terms of lines and circles

III. Classroom trials

A study of the "*Simple Geometry Method (SGM)*" was performed in two institutions. Two introductory mechanical drawing classes at Holy Cross High School in Northern Kentucky and two introductory computer aided drafting and design (CADD) classes at Northern Kentucky University participated in the study. Fifty-eight students in these four classes were participants.

Prior to the trials, students were not taught symbology, terminology and standards for dimensioning practices in engineering graphics. The SGM is intended for teaching importance of dimensioning a complex geometry completely and *avoid missing dimensions*. A pre-test consisting of two drawings (Figure 4. and Figure 5.) without dimensions and center lines were given to students. Students were asked to identify the radial and the linear dimensions that are needed to create the given drawings. Several facts were noted from the pre-test data about the students' observations of the drawings. These are: total number of radial and linear dimensions students identified, dimensions correctly identified, dimensions incorrectly identified, and missing dimensions (Table 1, 2, 3, and 4.). Types of missing dimensions (such as radial or linear) were also recorded.

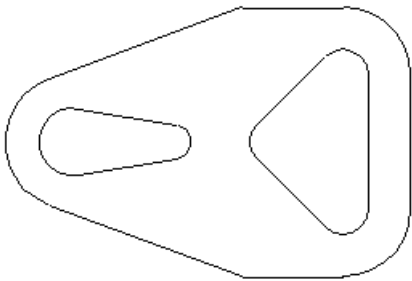


Figure 4. Drawing used in classroom trial 1

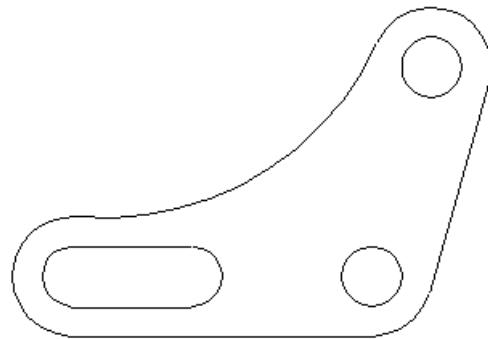


Figure 5. Drawing used in classroom trial 2

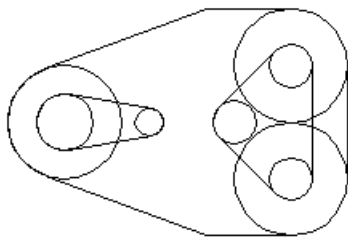


Figure 6. Drawing shown in Figure 4, in terms of lines and circles

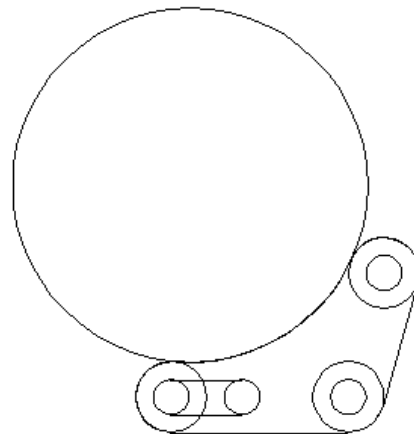


Figure 7. Drawing shown in Figure 5, in terms of lines and circles

Following the pre-test, students were taught the "*Simple Geometry Method (SGM)*" of illustrating a complex geometry in terms of simpler geometries, using the drawings shown in Figure 2a. and Figure 2b. The lesson emphasized that a drawing is composed of several lines and circles. Furthermore, the students should try to identify these lines and circles at the start. They should be able to recognize the types of lines (intersecting, tangential etc.) and types of circles (concentric, eccentric etc.). Immediately after the SGM lesson, students were given the same two drawings (Figure 4. and Figure 5.) again. This time they were told to identify the dimensions needed to create the drawings. Data from pre-test and post-test were compared to determine whether or not the students benefiting by applying the SGM method. The complete dimensions for the drawings are given in Figure 8. and Figure 9.

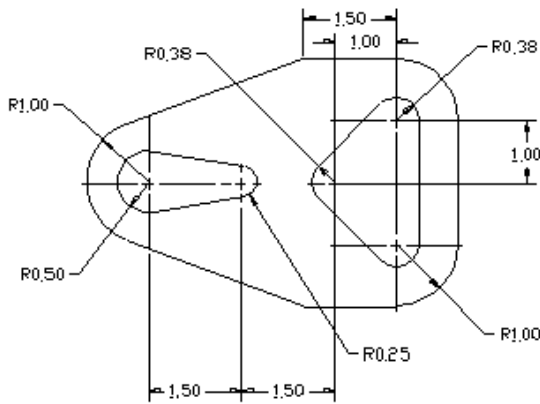


Figure 8. Completely dimensioned drawing of Figure 4.

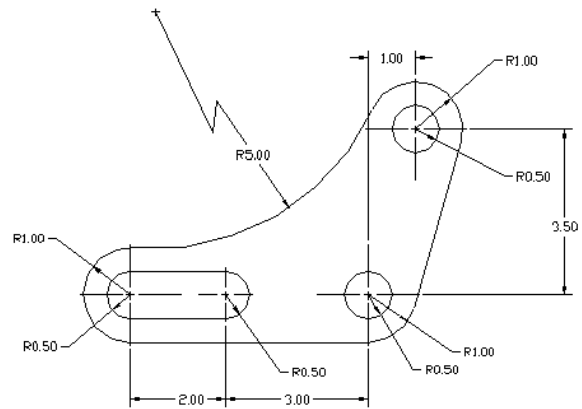


Figure 9. Completely dimensioned drawing of Figure 5.

IV. Results and Discussions

Data obtained from the pre-tests and the post-tests were analyzed to evaluate students' performances. The change in students' skill in dimensioning a drawing before and after learning the SGM method was studied. In all trials, average number of missing dimensions were found to be lower in post-tests than in the pre-tests (Table 1, 2, 3, and 4.).

Statistical analysis, t-test for comparing two means, was done for inferential tests². Out of eight trials in four classes, six trials showed significant improvement in student learning (i.e. less number of missing dimensions) at .01 level (Table 1,2,3, and 4.). Thus, once SGM was applied, students showed more accuracy in identifying the required dimensions for the drawings. However, one section at Northern Kentucky University did not show improvement at this level. Students also provided more dimensions or less dimensions than that are necessary for two drawings, in both the pre-tests and the post-tests (Table 5.). Providing more dimensions than that are necessary will not hinder creating the geometry as long as *all required* dimensions are provided. Out of eight trials in four classes, four trials showed minimized guesses (at 95% confidence level) by students in identifying required number of dimensions for two drawings (Table 5.). Apparently, students did less guessing in post-tests than in pre-tests when asked to identify required dimensions for drawings.

Table 1: Number of *missing* dimensions
Holy Cross High School
Section 1 (16 students)

Trial 1* (Figure 4.)		Trial 2** (Figure 5.)	
Pre-test	Post-test	Pre-test	Post-test
3	0	5	2
3	4	4	3
4	0	8	2
3	4	3	2
3	3	4	3
3	1	7	5
6	2	7	4
2	0	0	0
2	1	6	1
6	0	4	1
10	4	9	5
6	3	6	7
6	4	7	1
8	1	7	4
6	3	7	4
5	1	6	1
4.75	1.9375 Average	5.625	2.8125 Average
1.875	1.4375 Std.Dev.	1.71875	1.5625 Std. Dev.
t-value=-4.76163 at 99.99%		t-value=-4.84362 at 99.99%	

Table 2: Number of *missing* dimensions
Holy Cross High School
Section 2 (19 students)

Trial 1* (Figure 4.)		Trial 2** (Figure 5.)	
Pre-test	Post-test	Pre-test	Post-test
7	3	7	6
7	3	8	2
4	1	5	1
5	0	5	1
6	1	9	0
7	2	6	1
6	3	6	2
5	1	5	0
5	1	5	0
5	1	5	0
5	2	7	1
7	2	8	4
1	0	2	0
7	2	6	1
6	2	8	2
4	2	8	2
6	2	9	0
6	1	7	1
4	1	6	1
5.42105263	1.57894737 Average	6.42105263	1.31578947 Average
1.13573407	0.75900277 Std.Dev.	1.39058172	1.06371191 Std. Dev.
t-value=12.26 at 99.99%		t-value=12.71 at 99.99%	

Table 3: Number of *missing* dimensions
Northern Kentucky University
Section 1 (14 students)

Trial 1* (Figure 4.)		Trial 2** (Figure 5.)	
Pre-test	Post-test	Pre-test	Post-test
4	4	3	1
4	2	3	0
1	1	0	0
7	4	2	0
4	2	0	0
1	1	0	0
4	0	1	0
2	1	0	1
4	1	2	1
3	1	1	1
3	3	2	1
3	4	1	0
3	0	1	0
3	2	1	0
3.28571429	1.85714286 Average	1.21428571	0.35714286 Average
1.04081633	1.14285714 Std.Dev.	0.84693878	0.45918367 Std. Dev.
t-value=3.45796 at 99.81%		t-value=3.32894 at 99.74%	

Table 4: Number of *missing* dimensions
Northern Kentucky University
Section 2 (9 students)

Trial 1* (Figure 4.)		Trial 2** (Figure 5.)	
Pre-test	Post-test	Pre-test	Post-test
0	1	0	0
1	1	1	0
2	1	1	0
3	2	1	1
1	2	1	1
2	5	0	0
1	0	0	0
0	4	2	2
1	0	2	0
1.22222222	1.77777778 Average	0.88888889	0.44444444 Average
0.74074074	1.30864198 Std.Dev.	0.59259259	0.59259259 Std. Dev.
t-value=1.108 at 71.59%		t-value=1.590 at 86.88%	

*Required number of dimensions for trial 1 is, 11 (Figure 8.)
**Required number of dimension for trial 2 is, 12 (Figure 9.)

Table 5. Deviation from required number of dimensions indicated by students in pre-tests and post-tests *

<u>Holy Cross High School</u>								
Number of Students	<u>Section 1</u>				<u>Section 2</u>			
	<u>Trial 1**</u>		<u>Trial 2***</u>		<u>Trial 1**</u>		<u>Trial 2***</u>	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	1	2	1	2	3	0	1	6
2	9	7	0	1	4	0	5	2
3	2	1	1	2	2	1	2	1
4	3	3	1	2	1	0	3	1
5	11	2	3	3	3	1	4	3
6	4	1	6	0	3	0	0	1
7	2	2	3	4	3	4	4	2
8	1	0	2	0	4	1	4	0
9	3	3	2	1	3	1	1	0
10	6	3	1	0	1	1	4	0
11	7	3	5	5	3	2	7	1
12	2	3	6	7	5	0	8	1
13	1	1	1	1	2	2	2	3
14	5	1	7	4	4	1	2	1
15	1	2	1	3	4	3	4	1
16	1	1	2	1	5	0	2	2
17					4	3	3	0
18					3	1	3	1
19					1	1	4	1
Average	3.6875	2.1875	2.625	2.25	3.05263	1.15789	3.31579	1.42105
Std.Dev.	2.48438	1.10938	1.78125	1.5625	0.90859	0.86427	1.4903	0.99723
Significant	t=2. at 96.5%		t=.6 at 47%		t=6. at 99%		t=4 at 99.9%	

<u>Northern Kentucky University</u>								
Number of Students	<u>Section 1</u>				<u>Section 2</u>			
	<u>Trial 1**</u>		<u>Trial 2***</u>		<u>Trial 1**</u>		<u>Trial 2***</u>	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	2	1	5	3	0	3	0	2
2	1	3	3	1	4	2	2	0
3	3	4	1	1	1	0	0	2
4	5	4	4	5	5	1	2	2
5	3	1	2	4	9	7	1	1
6	2	1	3	5	8	0	4	3
7	6	3	0	0	13	5	1	1
8	3	2	1	1	11	4	6	6
9	2	2	2	1	3	3	1	1
10	1	4	3	2				
11	1	1	1	3				
12	6	3	0	2				
13	0	0	2	1				
14	0	2	1	0				
Average	2.5	2.21429	2	2.07143	6	2.77778	1.88889	2
Std.Dev.	1.57143	1.10204	1.14286	1.37755	3.77778	1.80247	1.4321	1.11111
Significant	t=.5 at 42%		t=.1 at 11.7%		t=. at 96.5%		t=.1 at 14%	

*Numbers are either more than or less than the required dimensions for the drawings

**Required number of dimensions for trial 1 is, 11 (Figure 8.)

***Required number of dimension for trial 2 is, 12 (Figure 9.)

V. Conclusions

The "*Simple Geometry Method (SGM)*" helped students understand the dimensioning of a drawing through understanding the geometry. Because recognizing of a drawing in terms of lines and circles and their characteristics helped students avoid missing dimensions. Classroom trials of the SGM method showed significant improvement of students' ability to avoid missing dimensions.

This method minimized guesses by students in identifying required dimensions for a drawing. Although most drafting software provides auto-dimensioning features, still students have to identify what features needs to be dimensioned to describe the drawing completely. Therefore, the SGM method will be useful to students in introductory CADD classes to avoid missing dimensions.

Bibliography

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