

Does the Glass Box Visualization Method Increase Student Learning Outcomes?

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Abstract

This research study compares incoming engineering technology (ET) students' learning outcomes in an introductory engineering graphics course without and with the use of a physical orthographic projection teaching aid (i.e., glass box). On average, there was not a statistically significant difference between the group ($n = 23$) that was not introduced to ($M = 126.04$; $SD = 10.00$) and the group ($n = 22$) that was introduced to the physical teaching aid ($M = 123.32$; $SD = 10.06$); $t(43) = 0.911$; $p = 0.367$, $d = 0.27$. This paper presents the methodology and results of the study along with construction directions and files for the glass box used.

Introduction

Studies have shown that spatial visualization is a vital skill for both engineering and engineering technology (ET) students, and that students' spatial awareness contributes to classroom success (Ahn, Freeman, & Potter, 2011; Alqahtani, Daghestani, & Ibrahim, 2017; Crown, 2001; Tumkor & deVries, 2015). However, incoming students often struggle to grasp introductory projection techniques (i.e., perspective and parallel projection) to translate three-dimensional (3D) objects onto a two-dimensional (2D) plane (e.g., paper or screen) by hand or mouse. Orthographic projections and more specifically multiview projections are of significant importance for students. Instructors traditionally use textbooks (Bertoline, Wiebe, Hartman, & Ross, 2008; Madsen & Madsen, 2011), graphical presentations, and/or some form of physical model (Tumkor & DeVries, 2015) to help students grasp the concept of multiview projection, with each method having varying levels of success.

The Idea. The concept of using a physical glass box, which can be unfolded to show the six principal views (i.e., front, top, right side, bottom, back, and left side) of a 3D object in third angle projection, as a teaching aid is of course not a new idea. The first known patent of the glass box dates back to May 1943 (U.S. Patent No. 2,319,162). However, despite a continued presence in introductory engineering graphics courses, the *impact of the glass box visualization method on student learning outcomes has never been quantitatively measured in a classroom setting.*

At Purdue Polytechnic New Albany, incoming Mechanical Engineering Technology (MET) students are required to take CGT16300, introduction to graphics for manufacturing, which generally averages 15-30 students per section. The course introduces students to the design process, sketching, engineering geometry and construction, visualization and projection methods, computer-aided design (CAD), and rapid prototyping. Starting in the fall of 2017, a physical orthographic projection teaching aid (i.e., glass box) was introduced and readily accessible (i.e., stored in the classroom and unmonitored) to the CGT16300 students for the entire semester. Generally, students passively witnessed the instructor use the glass box during discussions on projections types (e.g., multiview) and line types; however, for one class example students volunteered to draw in front of the class the front, top, and right-side views as shown in Figure 1. Erasable markers of different colors (i.e., different line types) were used as needed.

After the fall 2017 course ended, a comparison study was then performed on students' learning outcomes at two assessment points and across two conditions: without access to the glass box (i.e., control group; entire class from fall 2016) and with access to the glass box (i.e., investigational group; entire class from fall 2017). Curriculum (e.g., lectures, assignment, exams, schedules, etc.) for both course offerings were identical besides the introduction and availability of the glass box during the fall 2017 semester.

Production. In the spring of 2017, a design for the glass box was quickly conceived using AutoCAD®. Great care was taken to ensure the design would be user friendly, such as magnets and finger holes for ease of disassembly and subsequent reassembly. After the design was complete, the AutoCAD files were converted to DXF files and programmed into a laser cutter for the next stage of development. A sheet of 3/16" thick clear acrylic was chosen as the material for this project due to its durability and the ability to use erasable markers to draw orthographic projections. The 10" x 10" sides were quickly cutout and prepared for assembly. Standard hinges, screws, and nuts were used to allow the box to fold yet maintain its rigidity, while magnets were glued to specific corners to

allow quick and easy disassembly. A photo of the glass box can be seen in Figure 1.

In addition to the glass box, a wooden model and stand were also built to accompany it and help assist in classroom instruction. The model, in this case, was a 3D object designed to showcase a range of features (e.g. bosses, cuts, holes, fillets, etc.) and be used as a teaching aid inside the glass box. The model created for this project was taken directly from one of the students' learning modules (see Appendix). With the help of a Carvey® 3D carving machine by Inventables®, the model was carved out layer-by-layer, glued together, and finally stained to produce an attractive looking centerpiece. The model can be seen in Figure 2. As mentioned, a 12" x 12" x 18" stand was also produced for the glass box to sit on. In keeping with an engineering theme, the stand was designed with a truss-like support base and accompanying school logos were placed in the center of each side. The stand was laser cut much like the glass box sides and fastened together with finishing nails.

The authors have shared the files for making the glass box, stand, and 3D object on Dropbox: <https://goo.gl/WcWp4Q>.

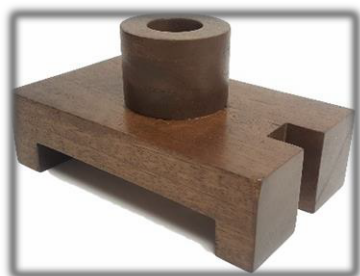


Figure 1: Model



Figure 2: Glass Box & Stand

Results

The sample for the comparison study consisted of 49 participants (5 females). The investigational group (entire class from fall 2017) consisted of 22 students (2 females) and the control group (entire class from fall 2016) consisted of 27 students (3 females). Over the two assessment points, a total of 141 points were possible for the students to earn. The first assessment point (91 points) was a homework assignment which contained multiple visualization exercises and multiple mechanical multiview sketching exercises (see Appendix). The second assessment point (50 points) was an exam which required students to use AutoCAD to draw a multiview drawing (i.e., front, top, right views) from a dimensioned isometric image (see Appendix). Upon analyzing individual grades, several outliers had to be removed from the fall 2016 group, and this was done using the quartile method.

In order to test the impact of the glass box on ET students' learning outcomes an independent *t*-test was conducted, and the test was found to be statistically non-significant, $t(43) = 0.911$; $p = 0.367$, $d = 0.27$ (see Table 1). The effect size for this analysis ($d = 0.27$) was found to exceed Cohen's (1988) convention for a small effect. These results (see Table 2) indicate that students in the investigational group ($M = 123.32$; $SD = 10.06$) did not perform better on the multiview assessments than students in the control group ($M = 126.04$; $SD = 10.00$).

Table 1. *t*-test for Equality of Means

	F	Sig.	<i>t</i>	df	Sig. (2- tailed)	Mea n Diff.	Error Diff.	Lower	Upper
Equal Variance s	1.01 1	0.184	0.91 1	43	0.367	2.72 5	2.99 1	-3.036	8.757
Equal Variance s Not Assume d			0.92 3	21	0.367	2.63 6	2.85 6	-3.304	8.576

Note: 95% Confidence of the Difference

Table 2. Descriptive Statistics

Group	<i>n</i>	Points	<i>M</i>	<i>SD</i>	Median	MIN	MAX
Fall ('16)	23	141	126.0 4	10.00	128.00	94.00	139.0 0
Fall ('17)	22	141	123.3 2	10.06	125.50	99.50	139.0 0

Discussion

Student learning outcomes did not improve with the introduction of the glass box visualization method. Instead, the average grade dropped several points between the control group ($M = 126.04$) and the investigational group ($M = 123.32$). However, it is possible that the students in the control group entered CGT16300 with higher levels of prior knowledge and experience concerning spatial visualization and/or orthographic projection. To ensure homogeneous sampling the researchers need to better screen incoming students and/or randomize students from a single course offering into two groups during the same semester. Starting in the fall of 2018, the Purdue Spatial Visualization Test: Rotations (PSVT: R), is given on the first and last day of class. “The PSVT: R is exceedingly used in different fields and programs of engineering” (Alqahtani, Daghestani, & Ibrahim, 2017) and has been shown to be a useful assessment tool in determining students’ spatial visualization skills (Branoff, 2000; Guay, 1980).

An additional limitation to this study was the use of a student grader in the fall of 2016 for both assessment points but used only for the first assessment in the fall of 2017. The course instructor graded the second assessment; however, the subjective nature of grading drawings introduces the possibility of grading variability. Generalizability of our findings are also limited due to our samples being predominately male and white.

Finally, exploring how new commercially available immersive and interactive technologies, such as virtual reality (VR), could be used to demonstrate the glass box visualization method need to be explored. VR may be a useful tool to improve students’ spatial ability and learning outcomes concerned with introductory engineering graphics courses.

Conclusion

For decades, the glass box visualization method has been a cornerstone in introductory engineering graphics courses and more specifically when teaching multiview projection. However, this research study finds that spending the time to create a physical glass box and introducing it to the incoming ET students will not improve learning outcomes. Using digital lecture slides and/or textbook references to the glass box visualization method will most likely save valuable instructor time and will largely have the same impact on the students. Further refinement of this experiment could potentially yield different results, however, just as the engineering graphics classroom has transformed from drafting tables to computer stations the physical glass box needs to be digitized.

References

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Appendix

First Assessment: Multiview Visualization Exercise Examples

Directions

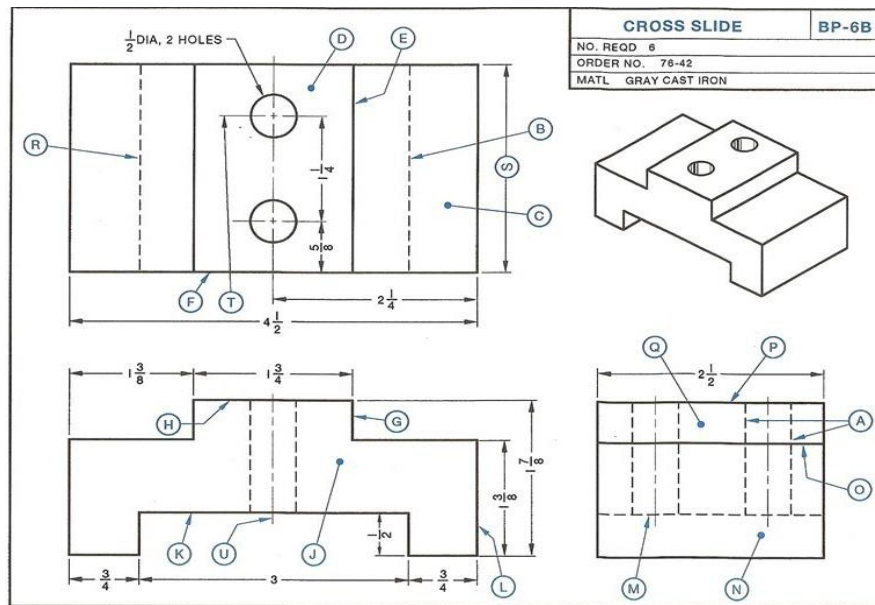
In the table, match the given surface letter from the pictorial drawing with the corresponding surface number from the multiview drawing for each view.

(A)

Surface	Top	Front	Side
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			
K			

(B)

Surface	Top	Front	Side
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			
K			
L			
M			



Cross Slide (BP-6B)

1. What material is used for the Cross Slide?
2. How many pieces are required?
3. What is the overall width (length) of the Cross Slide?
4. What is the order number?
5. What is the overall height of the Cross Slide?
6. What are the lines marked **A** and **B** called?
7. What do the lines marked **A** represent?
8. What two lines in the top view represent the slot shown in the front view?
9. What line in the right-side view represents the slot shown in the front view?
10. What line in the front view represents surface **Q** in the right-side view?
11. What line in the front view represents surface **D** in the top view?
12. What line in the top view represents surface **J** in the front view?
13. What line in the side view represents surface **D** in the top view?
14. What is the diameter of the holes?
15. What is the center-to-center dimension of the holes?
16. How far is the center of the first hole from the front surface of the side?
17. Are the holes drilled all the way through the slide?
18. What is the width of the slot shown in the front view?
19. What is the height of the slot?
20. Determine dimension **S**.
21. What is the width of the projection at the top of the slide?
22. How high is the projection?
23. What kind of line is **M**?
24. What kind of line is used at **Q** and **P**?

Directions

- File name shall be widget3.dwg
- Widget shall be drawn to true scale (1:1)
- Show only visible, hidden, and center lines (i.e. do not include dimensions, annotations, and construction lines) and eliminate double lines (i.e. lines drawn on top of other lines)
- Center line extensions shall be uniform (pick either .125 or .25)
- Lines shall be drawn on their correct layer
- Spacing between front, right, and top views = 1.00
- All holes = through holes
- Create/Print a .pdf of A-Size layout (widget3.pdf)
 - Include boarder/title block (update title block information)
 - Model scale = 1:1
 - Printer/plotter = Adobe PDF (if using lab computers)
 - Paper size = Letter
 - Plot area/What to plot = Layout
 - Plot offset (origin set to printable area) = X=0.00, Y=0.00
 - Plot/Paper scale = 1:1
 - Drawing orientation = Landscape
- Upload widget3.pdf to answer question

