AC 2011-2471: DEVELOPMENT AND IMPLEMENTATION OF CHALLENGE-BASED INSTRUCTION IN ENGINEERING GRAPHICS

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Development and Implementation of Challenge-Based Instruction in Engineering Graphics

Abstract

The focus of this paper is to discuss the challenge-based instructional (CBI) materials currently being developed for the Engineering Graphics course at the University of Texas - Pan American. This endeavor concentrates on student retention of the materials being studied, as well as the students’ ability to practically apply their new skills. Minority science, technology, engineering, and math (STEM) students have been found, in recent studies, to depart from STEM undergraduate fields to some extent because of the lack of real world connections to the subject matter being taught in the classroom. Also, the traditional way of teaching theory first and then assigning a task may actually stifle creative thought and innovation required in later STEM courses. Using a CBI approach, the target lessons will be, in effect, taught backwards. In other words, the students are presented with a challenge, and then, only when they have had the chance to think about the problem, the supporting theory is revealed. Our use of CBI is based on the How People Learn (HPL) framework for effective learning environments and is realized and anchored by the STAR Legacy Cycle, as developed by the VaNTH NSF ERC for Bioengineering Educational Technologies. The materials developed during the course of this study are collaboration between students and faculty members at the University of Texas-Pan American (UTPA) and South Texas College (STC), both Hispanic Serving Institutions (HSIs).

Introduction to UTPA Engineering Graphics

“Strive for perfection in everything you do. Take the best that exists and make it better. When it does not exist, design it.” ~ Sir Henry Royce

The Engineering Graphics Course is designed to teach Engineering Students (Mechanical, Manufacturing, Civil) the basics of Engineering Drawings. This includes the use of CAD software as well as hand sketching. The use of CBI during this course is intended to enhance the Engineering Graphics Course and data taken from grades on homework assignments, quizzes and projects as well as attendance and participation will indicate if this is the case. The use of CBI in STEM fields has proven to be effective in previous studies and will be the focus of this discussion1-3.

The lessons to be discussed are those in creating orthogonal multi-view sketches and drawings, isometric and oblique pictorial sketches, and two lessons in the creation of sub-assemblies using CAD software. For the purpose of design media and subject matter, certain educational toys were chosen for their basic geometry and inherent familiarity. These lessons will be based upon the “How People Learn” framework using the Star Legacy Cycle.

The Star Legacy Cycle
The Star Legacy Cycle is the basis of Challenge Based Instruction (CBI) and consists of the following:

![Flowchart of the Legacy Cycle](image)

Figure 1 - Flowchart of the Legacy Cycle

The Star Legacy Cycle challenges traditional ways of teaching, however has delivered such promising results, it has become very popular in the field of Education. The key is that the student is engaged and ready for the next phase and the new information. The students have questions before they have even heard the lesson. During the lesson, the students will be listening intently if for no other reason than to answer their own curiosity.

**Teaching Techniques – STEM Disciplines**

STEM students are need not only understand their fields, but also be able to adapt to changing technology and the evolution of science itself. They must have the ability to adapt and adjust their logic when presented with a novel problem to solve. This ability is known as Adaptive Expertise (AE). A STEM professional with AE can adapt their expertise in a novel situation.

There are two elements to AE: innovation and efficiency. Efficiency includes the general principles and concepts of the field. A student with this information would be able to solve most traditional problems a STEM professional might face. Innovation includes the ability of the student to solve novel problems using the same knowledge. These two elements of AE must be developed together in order to achieve further success in adaptive situations.

Unfortunately, in STEM education programs it is the conventional approach to teach efficiency first. Only after a certain level is achieved, will STEM students be taught the lessons required for innovation. Studies have shown that a focus on efficiency early in a student’s education can result in actually suppressing innovation or decreasing students’ innovative performance in adaptive situations. Students must be able to think for themselves, applying the knowledge in they have gained in their studies.
Other studies have shown that STEM students depart from the field because of too few connections to the real world. Constructive toys such as LEGO®s have been used in studies to make real world connections with the subject matter. It is through the use of familiar toys that this study attempts to make those connections.

Applying CBI to Engineering Graphics

The lessons discussed below have been created with the benefit of this information. First and foremost, the student must remain interested in the subject matter. The use of familiar real world objects in these exercises engages the students’ interest, as well as makes a connection to the real world. When combined with CBI techniques, this allows the student to develop innovative skills as well as efficiency.

The Groups

Below Figure 2 & 3 show the numbers of students in each of the groups as well as the percentage of each group that are of Hispanic decent. These lessons can be applied to students of any ethnicity, but it should be noted that the students at UTPA are predominantly Hispanic. Each group will be given the same homework, quizzes, and exams. However, the control groups in the Fall 2010 and subsequent semesters will not experience the CBI Lessons 1 & 2. This is so a comparison can be made within a given semester rather than just between semesters.

<table>
<thead>
<tr>
<th>Numbers of Students in each Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab #3 Control - Spring 2011 (no CBI)</td>
</tr>
<tr>
<td>Lab #2 Experimental - Spring 2011</td>
</tr>
<tr>
<td>Lab #1 Experimental - Spring 2011</td>
</tr>
<tr>
<td>Lab #3 Control - Fall 2010 (no CBI)</td>
</tr>
<tr>
<td>Lab #2 Experimental - Fall 2010</td>
</tr>
<tr>
<td>Lab #1 Experimental - Fall 2010</td>
</tr>
<tr>
<td>Lab #3 - Spring 2010 (no CBI)</td>
</tr>
<tr>
<td>Lab #2 - Spring 2010 (no CBI)</td>
</tr>
<tr>
<td>Lab #1 - Spring 2010 (no CBI)</td>
</tr>
</tbody>
</table>

Figure 2 - Numbers of Students in Each Group
CBI Lessons

Lesson 1: Introduction to Multi-view Drawings – Snap Cubes

The Challenge:

This exercise will take place during the second week of Engineering Graphics Lab as an introductory assignment. It is designed to use a simple example to make the students think about the format of a multi-view drawing.

Generate Ideas:

Show a multi-view/isometric drawing showing a basic shape created by adding cubes together. The drawing is purposefully without color and as basic as possible. At this point, the information the students receive is limited to the simple line drawing in Figure 3.
Possible questions:

1. What are the different views?
   a. The students will try to answer, but do not have all the facts. This is the optimum time to introduce the concept of a multi-view drawing. The instructor should now inform the students about the top, front, and right side views.

2. Why are things the same size even though they are at different distances?
   a. This question introduces the concept of parallel projection. Parallel projection is a drawing technique in which lines that are parallel on the object are parallel in the drawing. This differs from the more artistic style of perspective projection. The instructor should show an example of perspective projection to distinguish parallel projection as the preferred method for the multi-view lesson, as well as for pictorial sketching in Lesson 2.

Multiple Perspectives:

Show students an Isometric Drawing of the same Basic Block Shaped Part made from different colored Snap Cubes. Ask the students to build what they see in the drawing. Ask them to match the color of each snap-cube.
Possible questions:

1. Do the colors in the drawing help to construct your block part?
   a. With the presence of colors in the multi-view drawing, the student can more easily see the orientation in each view with respect to the isometric view’s orientation.

2. Why do the pink, brown, and blue blocks show up in all three views?
   a. This question is designed to enforce standard orientation as before. By seeing the position of each colored snap-cube in each view, the student can better understand the orientation of each view.

3. Why do the black, gray, and yellow blocks only show up in one view each?
   a. This question simply points out that different views show different features of the part.

Research and Revise:

Now the instructor can reveal the lesson of multi-view drawings and give the students some examples in class using standard sketching tools (triangles, ruler, pencil, etc.). Below are a couple of sketches done as an example of how to use geometry to produce a multi-view drawing. Figure 5 shows a sketch drawn while filming a tutorial movie on this topic. The movie is accessible on the UTPA-EG website. The darker lines are the actual finish product, but notice the other lines on the drawing. A miter line is used to derive the depth dimension for the right side view from the top view. The use of extension lines and miter lines is the purpose for the format taught earlier in this lesson. Figure 6 shows an example drawn in class. The instructor should perform at least two example sketches in class before issuing a homework assignment.
Test Your Mettle:

Assign homework (4 multi-view worksheets available on the UTPA-EG website) designed to exercise the skills learned during this exercise. This is the same homework assignment that the control group will receive. At this time the students are still in the lab and have the opportunity to interact with the instructor and ask questions. During this time, the instructor will give one-on-one instruction to the students who request help. The students are required to complete the worksheets and hand them in the following week. The students are also required to generate multi-view drawings for parts drawn in a CAD lesson. This is to reinforce the concept that a multi-view sketch with dimensions can help when creating a 3D model. This also insures that all students use the same dimensions for the CAD lesson. This is important, because these parts are to be used in later lessons when creating assemblies using CAD software.

Go Public:

Quiz students for a grade at the end of the lab. Quiz will consist of displaying a block shape in isometric form and asking students to complete a multi-view sketch given the top and front
views. The quiz is designed to test the students on the concept of orientation of the multi-view sketches. Students are asked to use the skills taught during the lesson to create the right side view. All test groups receive the same quiz and homework assignments. There will also be a specific question on the first exam where the students will use the skills learned during the multi-view and pictorial sketch lessons.

**Discussion of Lesson 1**

*Lesson 1* is an introductory lesson in more than one way. First and foremost, it introduces multi-view drawings as a fun exercise where they get to play with toys. It introduces them to the Snap Cubes which will be used later in other lessons. And this lesson introduces the CBI “thought process” to the students.

When seeing a multi-view drawing for the first time, the students will automatically know what they are looking at when it is a simple part. When the part is introduced made of colored snap cubes it becomes even more obvious. The process, trying first and then learning more once the experience of trying has yielded wisdom, is the very essence of this CBI techniques and the focus of this study.

**Lesson 1 Preliminary Results**

<table>
<thead>
<tr>
<th>Lab #</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>92.27% Lab #3 Control - Spring 2011 (no CBI)</td>
</tr>
<tr>
<td>#2</td>
<td>91.92% Lab #2 Experimental - Spring 2011</td>
</tr>
<tr>
<td>#1</td>
<td>91.20% Lab #1 Experimental - Spring 2011</td>
</tr>
<tr>
<td></td>
<td>89.43% Lab #3 Control - Fall 2010 (no CBI)</td>
</tr>
<tr>
<td></td>
<td>92.12% Lab #2 Experimental - Fall 2010</td>
</tr>
<tr>
<td></td>
<td>96.00% Lab #1 Experimental - Fall 2010</td>
</tr>
<tr>
<td></td>
<td>84.07% Lab #3 - Spring 2010 (no CBI)</td>
</tr>
<tr>
<td></td>
<td>87.04% Lab #2 - Spring 2010 (no CBI)</td>
</tr>
<tr>
<td></td>
<td>74.57% Lab #1 - Spring 2010 (no CBI)</td>
</tr>
</tbody>
</table>

*Figure 9 - Lesson 1 Homework Results*
All groups were given the same quiz and homework assignments. The experimental groups were asked to complete Lesson 1 as outlined above. The control groups were not required to complete Lesson 1. The new CBI curriculum is working. There is a 10.6% improvement in homework grades and a 14.9% improvement in quiz grades from the Spring 2010 semester to the Fall 2010 semester. This is due to the introduction of the CBI material as well as the new EG website. The control groups benefited in the form of better planned lessons but did not benefit from the CBI lessons. During the two CBI semesters, there is a 1.61% difference in quiz grades between experimental and control groups. The results suggest that the CBI groups were able to perform better due to Lesson 1; however the inconsistency shown in the Spring 2011 semester indicates more data is needed before results can be considered conclusive.

**Lesson 2: Introduction to Pictorial Drawings – Snap Cubes and Special Graph Paper**

The Challenge:

This exercise will take place during the third week of Engineering Graphics Lab as an introductory assignment. It is designed to give the students tactile experience making the shape with Snap Cubes before attempting to sketch a pictorial drawing. This assures that the student is visualizing the shape accurately before the pictorial sketches are started.

| Lab #3 Control - Spring 2011 (no CBI) | 91.30% |
| Lab #2 Experimental - Spring 2011 | 95.19% |
| Lab #1 Experimental - Spring 2011 | 89.66% |
| Lab #3 Control - Fall 2010 (no CBI) | 88.50% |
| Lab #1 Experimental - Fall 2010 | 90.90% |
| Lab #2 Experimental - Fall 2010 | 90.30% |
| Lab #3 - Spring 2010 (no CBI) | 71.43% |
| Lab #2 - Spring 2010 (no CBI) | 73.75% |
| Lab #1 - Spring 2010 (no CBI) | 79.71% |

**Figure 10 - Lesson 1 Quiz Results**

| Lab #3 Control - Spring 2011 (no CBI) | 91.30% |
| Lab #2 Experimental - Spring 2011 | 95.19% |
| Lab #1 Experimental - Spring 2011 | 89.66% |
| Lab #3 Control - Fall 2010 (no CBI) | 88.50% |
| Lab #1 Experimental - Fall 2010 | 90.90% |
| Lab #2 Experimental - Fall 2010 | 90.30% |
| Lab #3 - Spring 2010 (no CBI) | 71.43% |
| Lab #2 - Spring 2010 (no CBI) | 73.75% |
| Lab #1 - Spring 2010 (no CBI) | 79.71% |
Generate Ideas:

Give the students Snap Cubes so that they are able create the shape above.

Possible questions:

1. Why does the cavalier sketch look stretched?
   a. This is intended to point out the differences between the different types of pictorial drawings.
   b. The cavalier sketch looks stretched because the depth lines are drawn to the same dimension as the actual part. When using the oblique graph paper, this produces a stretched image.

2. Why does the cabinet sketch look right?
   a. The cabinet oblique has depth lines that are one-half the actual depth. When drawn using the oblique graph paper, the part looks closer to what the human mind perceives as correct.

3. How is the isometric pictorial different from cavalier and cabinet pictorials?
a. The isometric pictorial has vertical lines in the height dimension and width and depth lines at ±30°.

b. The cavalier and cabinet oblique pictorials have vertical and horizontal lines for height and width, but the depth lines are at 45°.

Multiple Perspectives:

Ask students to create multiple shapes from pictorial drawings. The instructor can give some examples using shape from previous multi-view exercises. The students should be following along until they feel comfortable trying on their own.

Research and Revise:

Give students other shapes to draw using the standard pictorial views so that they may familiarize themselves with the process during the lab. A tutorial movie is available on the website. Students can access these movies to practice and review before quizzes and exams. Below is a screenshot showing some of the examples drawn during the tutorial movie. These are shapes taken from the 4 worksheets completed in Lesson 1. The students are already familiar with the shapes, so they can concentrate on the subject of pictorial sketches.

![Figure 12 – Sample Screenshot from Pictorial Sketches Tutorial Movie](image_url)

Test Your Mettle:

Assign homework designed to exercise the skills learned during this exercise.

The figure below shows the puzzle cube the students are required to draw and model (both pictorial sketches and CAD) for homework. This is the same homework assigned to the control group.
Go Public:

Quiz students for a grade at the end of the lab. Quiz will consist of displaying a block shape in isometric form and asking students to draw cavalier and cabinet oblique pictorial sketches. All students receive the same quiz. There will also be a specific question on the first exam where the students will use the skills learned during the multi-view and pictorial sketch lessons.

Discussion of Lesson 2

Lesson 2 introduces pictorial drawings as a fun exercise where they get to use the familiar snap cubes. They will just need to know what shapes to make. The illustration above will suffice to begin their pictorial lessons. It is an isometric view accompanied by an exploded view of the cube puzzle the students will be required to draw.

The illustration gives the students the picture of the pieces that they need to build a snap cube replica. This assures the instructor that the student sees and understands the isometric view and is ready to continue to Cabinet Oblique and Cavalier Oblique drawings. The three different types of pictorial views have their own unique geometry as depicted below using UTPA Engineering Graphics Paper (available in PDF format at http://mece.utpa.edu/~EG). The pictorials below are an isometric, a cavalier oblique, and a cabinet oblique of the same part:

Notice that for the isometric pictorial there are lines at positive and negative 30 degrees (from horizontal) as well as vertical lines, and the cavalier oblique and cabinet oblique are orthogonal (height and width) except for the 45 degree (depth) lines.

Lesson 2 Preliminary Results
The experimental groups were asked to complete Lesson 2 as outlined above. The control groups do not know that Lesson 2 exists. Although not as drastic as Lesson 1, the new CBI curriculum is also working for Lesson 2. There is a 7.5% improvement in homework grades and a 2% improvement in quiz grades from the Spring 2010 semester to the Fall 2010 semester. These results suggest that the CBI groups were able to perform better due to Lesson 2 but similar to Lesson 1, the inconsistency shown in the Spring 2011 semester indicates further study is needed.

Lesson 3: A Lesson in Sub-Assemblies – CAD – Snap Cubes

The Challenge:

Give students an advanced lesson in sub-assemblies using snap-cubes as subject matter. This exercise will take place during the eighth week of Engineering Graphics Lab. It is designed to give the students tactile experience making the shape with Snap Cubes before attempting to create a CAD model. This assures that the student is visualizing the shape accurately before the parts and assemblies for this lesson are started. This lesson can be viewed in website form at the following web address: [http://mece.utpa.edu/~EG/Camp_F/Tent_5.html](http://mece.utpa.edu/~EG/Camp_F/Tent_5.html)
Generate Ideas:

Give the students dimensions of a Snap Cube so that they are able create a part file in SolidWorks. From this, they can create an assembly of 3 sub-assemblies of a puzzle cube. At this point in the course, the students already possess the CAD skills to complete the basic task: creating sub-assemblies and using them to create an overall assembly. However, the lesson is about advanced techniques where the students are using “smart mates”. This technique saves time and effort when creating assemblies containing more of one part or similar parts. When the students are building their real-life snap-cube puzzle cubes, they should be thinking about how to assemble their 3D model sub-assemblies, and ultimately the overall assembly of the cube puzzle.

Possible questions:

1. What units should be used when modeling the part? The size of the part often determines what units are used. For example, the distance between cities is usually measured in miles or kilometers. Would it not seem ridiculous to ask for that same distance in units of inches or centimeters?
2. Should you create a new part template? Do you have to?

Multiple Perspectives:

Ask students to create puzzle part shapes from snap cubes first. They can then create a sub-assembly of each puzzle piece using their snap cube part drawn earlier.

Possible questions:
1. What type of tolerance fit is between each snap cube? The snap-cubes have an Interference Fit between the mating surfaces. This question is meant to reinforce the regular EG curriculum with a real life example.
2. How do the pieces stay together?
3. What keeps them lined up with each other (sides flush)?

These questions are designed to stimulate thought about what type of mates should be used when modeling the sub-assemblies. The friction between each cube holds them in place in real life. There will have to be mates that accomplish the same end when they are modeling their sub-assemblies.

Research and Revise:

Ask students to model the entire puzzle cube assembly using component sub-assemblies.

Possible questions:

1. Do the sub-assemblies stay together when constructing the entire cube?
2. Why should you make each puzzle piece as a sub-assembly?
3. Do the snap-cubes interfere when assembling the puzzle components?
4. What surfaces are being used to mate the parts together?

These questions are designed to stimulate thought on the task at hand….creating a 3D assembly model using advanced techniques taught in this lesson. A tutorial movie on the EG website is also available.

Test Your Mettle:

Assign homework designed to exercise the skills learned during this exercise. This would include improving the “smart mates” for their models. After they have watched the tutorial, they will be able to greatly improve their snap-cube parts’ “smart mates”. This skill will be advantageous while working on the next lesson and the final project.

Go Public:

The students are assigned a final project at the end of the semester by which Lesson 3 shall be measured. The final project requires the skills learned in Lessons 3 & 4.

Discussion of Lesson 3

Building sub-assemblies in CAD software is an important concept needed later in more advanced lessons. It is important that students grasp the concept of creating assemblies within assemblies. This saves on processor time when rebuilding your assembly (which happens every time you move, rotate or save the model), when rendering, and saves operator time when making modifications. Advanced assembly techniques are also introduced during this lesson. The use of
the snap cubes allows the student to concentrate on the lesson and not what the shape looks like. The snap cubes themselves are the individual parts. Students need only make one 3D model and then save it with different colors. The puzzle component sub-assemblies are made up of these colored snap-cubes. The overall assembly is putting all of the puzzle components together.

**Lesson 3 Preliminary Results**

*Lesson 3* is a supplementary lesson, but was integrated into the Engineering Graphics curriculum for all three groups during the Fall 2010 semester. For now, the only comparison that can be legitimately made at this time is one between the Spring 2010 and Fall 2010 semesters. Please see the sections with the headings “*The Final Project - Preliminary Results*” for the preliminary results of *Lessons 3 & 4*. Unfortunately, *Lesson 3* cannot be separated from a control group during each semester.

**Lesson 4: A Lesson in Sub-Assemblies & Working Drawings – CAD – Lincoln Log House**

This exercise will take place during the eighth week of Engineering Graphics Lab. The students are required to design a Lincoln Log Fortification. They are required to generate a complete set of working drawings to manufacture and assemble their design. It is designed to give the students subject matter that is familiar so that the focus of the lesson can be emphasized. Lincoln Logs assemble in the most basic of ways. The mechanics of the assembly is obvious so as not to add to the difficulty of the lesson. The students should be able to assemble their original designs (Lincoln Log Houses) using the CAD software without worry of complicated geometry or mechanics. This lesson can be viewed in website form at the following web address:

http://mece.utpa.edu/~EG/Camp_G/Welcome.html

Generate Ideas:

Give the students dimensions of Lincoln Logs and accessories so that they are able create part files in SolidWorks. From this, they can create an assembly of Lincoln Log House.
Possible questions:

1. How many types of parts are there? How many roof components? How many different sizes of logs? These questions lead to the creation of a parts library. These parts, once modeled, can be used to create an infinite number of unique designs.

2. What units should you use when modeling these parts? Does it matter what units are used? Should you make a new template? They are shown dimensions in inches. It would make sense for them to use inches to avoid confusion concerning scale. They already know how to create a part template file. This is an opportunity to apply this skill on their own.

Multiple Perspectives:

Ask students to create rough sketches of their Log House first, and then create the assembly using their Lincoln Log parts drawn earlier. Students are encouraged to play with the Lincoln Logs brought to the lab. Students can see how the pieces fit together in the real world before attempting to create a solid model assembly.

1. What holds the Lincoln Log House together? Why doesn’t it fall down under its own weight? These questions are designed to help students how the parts must be assembled using CAD software. By understanding the real life relationships between parts, one can assemble a more accurate model.

2. What kind of smart mates could be employed when assembling your log fortress? Students can use the “smart mates” lesson to increase their efficiency on this project. This would allow them to try out many ideas without wasting too much time.

3. How would you simulate the appearance of the wooden logs, chimney, and roof components? The use of textures to render parts with realistic surfaces and shadows is part of this lesson as well.
Research and Revise:

Students are required to create a unique design in the form of a battlement. The students are encouraged to do research online for design ideas for defensive structures. And the students may simply play around using the CAD software to explore different design ideas. With unlimited pieces, there are no limits on size. However, the students are required to create working drawings showing the dimensions of each part and all of the assembly steps to build their battlement. Available on the EG website is a tutorial movie to instruct the students what is required for this assignment. They are shown an example, but not step by step instructions.

![Figure 17 - Examples from Set of Drawings Shown in Tutorial Movie](image)

Test Your Mettle:

Students will be required to complete their original design as part of their homework assignment. An example is given in the form of tutorial movies showing the necessary information to draw each piece. Each student will produce a complete set of working drawings for their design including dimensioned parts drawings and assembly instructions with a bill of materials (BOM).

Go Public:

The students are assigned a final project at the end of the semester by which Lesson 4 shall be measured. The final project requires the skills learned in Lessons 3 & 4.

Discussion of Lesson 4

Lesson 4 is designed to teach the students how to follow certain specifications (e.g. parts dimensions) and create a small parts library containing the building blocks of an unlimited amount of unique log house designs. The parts are 3D models, so there is no limit to the size and number of logs the students can use. Every kid wants to have unlimited pieces in any set of toys. Other set type toys would include Lego’s, Erector Sets, even toy robots. Now back to Lesson 4. Because the parts (logs) are similar, and in many cases the same part, pattern tools as well as
“smart” assembly techniques can be used in the CAD software. A lesson in rendering is also covered during this lesson. The coloring and texturing of the logs and accessories adds the uniqueness of each student’s design.

Lesson 4 Preliminary Results

Lesson 4 is a supplementary lesson, but was integrated into the Engineering Graphics curriculum for all three groups during the Fall 2010 semester. The only comparison that can be made at this time is one between the Spring 2010 and Fall 2010 semesters. Please see the section with the heading “The Final Project - Preliminary Results” for the preliminary results of Lessons 3 & 4.

THE FINAL PROJECT - An Advanced Lesson in Sub-Assemblies – CAD – IKEA Furniture

Figure 18 - Example of IKEA furniture for Final Project

This is not a CBI exercise, but can be used a measure of the effectiveness of CBI Lessons 3 & 4. This exercise will take place at the end of the semester as the final project. It is designed to test the students the ability to take a design and modify it using the skills acquired during this course. All students will be required to complete this project.

The IKEA website is a veritable buffet of designs that can be simplified. Students will be required to draw their 3D parts to estimated dimensions. Only overall dimensions are on the website. A minimum of 10 unique parts will be required for the assembly. An example (a complete set of working drawings for a simplified IKEA design) will be given. A tutorial movie will show the details of the example set of drawings, however step by step instructions are not given. This lesson can be viewed in website form at the following web address:
http://imece.utpa.edu/~EG/Camp_H/Welcome.html

This lesson is designed to allow the students to get creative while being required to create a certain design. The students are picking their own piece of furniture consisting of at least 10
different parts. In essence, a skilled craftsman must be able to take these drawings and build the student’s design. The standard hardware and other miscellaneous pieces that accompany IKEA furniture are taken out of the equation. Students are asked to use “pin and glue” type designs. If screws or bolts are required it is allowed, but not counted a separate parts because the software comes with a library of fastener hardware. Students are further challenged by the fact that only the overall dimensions of their chosen furniture is on the IKEA website. They must decide the actual dimensions of their parts within their assembly as well as how it will fit together.

The Final Project - Preliminary Results

The chart above shows the Average Final Project Grade received by UTPA Engineering Graphics students in the Spring Semester vs. the Fall Semester of 2010.

In the spring 2010 semester, students were asked to make parts and assembly drawings for any subject matter they wanted. Students were required to have parts drawings, assembly drawings, and a complete bill of materials. The assembly shown in their drawings was required to have at least 5 unique parts (½ the number of parts required for the CBI semester). None of the CBI-based lessons mentioned above were implemented during the spring semester.

During the fall semester, students were given CBI Lessons 3 & 4. The general guidelines are above in The Final Project and are arguably more defined in nature but the assembly required is twice as complex (twice as many parts required in fall semester). The students were given a much more restricted range of objects they could choose for the subject of their final project, yet none chose the same piece of IKEA furniture.

Overall Results
One can see from the graph above, there is a clear problem with absences at the end of the semester. Groups 1 & 2 had fewer students absent during this period. Similarly, the graph below shows the percentage of students’ participation in the final project during the fall 2010 semester. This is, at least in part, due to loss of interest in the subject matter by the end of the semester. By adding CBI exercises which allow the students to have some fun while learning, more students stay interested and complete the course. More data will be collected as this study continues.

![Number of Absences during Fall 2010 Quizzes](image)

**Figure 20 - Number of Students Absent During Fall 2010 Quizzes**

General Discussion and Conclusions

The Engineering Graphics Course at The University of Texas – Pan American (UTPA) has been, and will always be, evolving. Currently this study is in its second semester of existence. More data must be gathered. However, the preliminary results show that the CBI lessons are having an impact in the Engineering Graphics Lab. By challenging these students with these few lessons as a supplement to the Engineering Graphics curriculum, the students were able to enjoy themselves and learn valuable skills simultaneously. They have learned how to use sketching tools and techniques in Lessons 1 & 2 (multi-view and pictorial sketching) and to make a connection from real life relations between actual parts and virtual parts used to model assemblies in Lessons 3 & 4 (advanced assembly techniques). The preliminary results indicate the students who experienced the CBI lessons, scored 6.3% better on relevant homework assignments, and 6.1% better on relevant quizzes, as well as scoring 15.5% higher on the final project. The data also shows that quiz attendance was more consistent in the CBI groups (1 & 2) in Fall 2010 (Labs 1, 2 & 3 –

![Final Project Participation](image)

**Figure 21 - Percentage of Students who participated in Final Project - Fall 2010 Semester**
96.1%, 93.1%, & 92.0% respectively). Student participation for the final project was 22.2% higher in the CBI groups. The use of CBI in Engineering Graphics yields results in the form of involved students that retain what they have learned.

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References