3D Modelling—Architectural CAD
3D Modelling (Inventor)—Mechanical CAD
Activity Plans
# 3D Modelling—Architectural CAD

# 3D Modelling (Inventor)—Mechanical Cad

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Youth Explore Trades Skills
Symbols and Standards

Description
In this activity the teacher will give an orientation to the symbols and conventions of Architectural CAD. Industry common symbols are used for most of the fixtures and hardware that go into any building, and these can be either drawn by the designer or accessed through the Internet.

Lesson Objectives
The student will be able to:

- Define blocks
- Explain what standards are
- Draw their own symbols
- Copy the symbols and place them in a drawing with correct orientation
- Use the stretch command to pull windows to the correct size
- Save the block as a drawing for insertion into the building drawing in Activity 12: Drawing of a Simple Building (Architectural CAD)

Assumptions
The student will:

- Know how to login to a computer and open up the software
- Know how to save the drawing as a named file in their own directory
- Have been introduced to the basic commands for drawing 2D objects

Terminology

**Block**: a predefined architectural object that is made or found within a library on the computer, on the network or the Internet. Blocks are available for all aspects of design regardless of specialty of the designer.

**Scale**: a drawing that is enlarged or reduced from its original size, usually expressed as a fraction in imperial measurement. The most common architect’s scale is ¼ inch to the foot, expressed as Scale ¼” = 1'-0". In metric measurement, scale is expressed as a ratio (e.g., 1:50, meaning 1 mm in the drawing equates to 50 mm in the actual work). The actual building measure would be multiplied by the scale factor.

**Standard**: an industry-agreed use of units (whether imperial or metric), drawing layout, layer conventions, line types, dimensioning, and plot styles.
Standards: industry-agreed ways and means for the use of designers to have a common language for common objects and rules used in all drawings.

Stretch command: used to pull objects from the length they are drawn to a desired length, longer or shorter. For example, if a wall in the drawing of a building must be stretched to make it 2' longer, the portions of the wall that need to be stretched are picked, a base point (usually an intersection on the wall) is picked, and then using polar linear directional command (e.g., @2’>0), the wall can be lengthened this precise amount.

Trim: where lines, circles, and all other linear objects intersect and cross over each other in a manner that is not desired, the excess portion of the lines can be trimmed using the Trim command.

Estimated Time
60 minutes

Recommended Number of Students
20, based on BC Technology Educators’ Best Practice Guide

Facilities
Computer lab installed with CAD software (Google SketchUp, AutoCAD, Cadopia, Vector works, etc.) and Internet access

Tools
Projector with computer and speakers installed with CAD software

Materials
Student activity handout with instructions

Resources
Instructional video for teacher and students to follow:
- 11.1: Changing Your Model Space
- 11.2: Drawing Architectural Blocks for a Building

About Unit Conventions—Autodesk AutoCAD
Explanation of some of the conventions for measurement

Architectural Symbols
A good example of a simple set of blocks
http://cms.cerritos.edu/uploads/dmussaw/symbols.pdf with permission from:
David Mussaw, Cerrito College, California.
Teacher-led Activity

The intent of the teacher-led activity is to demonstrate the setting up of the model space in the correct architectural format to ensure the blocks are drawn to the scale of the drawing. The following should be demonstrated:

- Projecting the completed drawing (Figure 1)
- Mouse movement (scroll in/out, right/left buttons, pan)
- Command line: inputting commands (zoom, limits, grid, etc.)
- Coordinate entry and the line command (absolute, relative, polar)
- Use of a pick window (right click and hold). If the pick window is green (in AutoCAD 16), multiple objects can be selected by just touching them with the window. If the pick window is blue, the objects must be wholly inside the window.

Student Activity

Students will follow the student activity and draw their own set of blocks, then save that drawing for insertion into the small shed drawing in the Drawing of a Simple Building (Architectural CAD) activity. This will be done after the small shed file has been started and the drawing has been set up with the correct units, limits, Dimstyle, grid, and snap.

Assessment

Assessment will be on a “done or not done” basis. The student must have completed all the symbols required:

- Door symbol
- Light fixture
- Outlet fixture
- Window

The file must be saved and/or printed with the student’s name inserted in the drawing using the text tool.

Important Note

It is easily possible for students to copy each other’s work and resave the file under their own drive and file name. It is important that students save the block drawing with their first name included in the file name.

If the teacher suspects that a student has copied the drawing file from another student, follow the procedure below. This applies for all recent versions of AutoCAD.

- Have the suspected student open their file, if it is not already open.
- Type the word time.
- The drawing editing time will be displayed.
- If the time is mere minutes or less than an observed time of other students, then the teacher would have evidence of cheating/copying. The student would then have to start the drawing again from scratch or take a zero mark on the activity.
Student Activity

Using the software, create the drawing and produce your own architectural blocks using the drawing set-up and the commands that have been demonstrated to you. In this activity and in the small shed drawing in the Drawing of a Simple Building (Architectural CAD) activity, all units will be done using imperial measurement. The settings for the drawing will be architectural in the units dialog box and the dimstyle dialog box.

Your assignment is to draw all of the drafting symbols found in Figure 1 below (you do not need to draw the labelled leaders).

1. **Switch symbol.** A switch symbol is just the letter S inserted as a text object. The height of the text should be 4". Type **TEXT**. Follow the prompts by pressing **Enter** for each one until you get the prompt to click on the location where you want the S to be placed. Three- and four-way switches are noted with superscripts, for example \( S^3 \) and \( S^4 \) in AutoCAD 16 or by typing the number \( S3 \) or \( S4 \) in the same text entry box in other versions of AutoCAD or other software packages.

2. **Door symbol.** The door symbol is made with a 36" vertical line. The arc of the door is made by using the circle command. The centre of the circle is started at the bottom end of the line with a radius of 36". A line must be added to trim out three-quarters of the circle. This is done by drawing a line starting at the bottom end of your first line and drawing it horizontally through the circle any distance. Type **TRIM**, press **Enter**, select the lines and the circle, and press **Enter**. Then pick the parts of the circle you want to trim out and delete the extra line. Two vertical lines 6" long should be added to the end of the arc and the base of the door to represent the thickness of standard walls as they are in all new frame construction (Figure 2).
3. **Light fixture symbol.** A light fixture symbol is just a 4” circle with line parts at the north and south ends of the circle. This is done by drawing two vertical lines starting at the centre of the circle for a distance of about an inch outside the circle. Copy the whole object and place it away from your light fixture, as you will be using it to make your outlet symbol. The interior of the lines can be trimmed out using the Trim command.

4. **Outlet symbol.** With the copy of the light fixture, use the Offset command to offset the centre lines of the light fixture 1” on either side of the centre line. Type **OFFSET**, pick the two lines in the centre of the circle (it looks like one but you know there are two), press **Enter**, then enter the distance of 1” (be sure to put in the quotation mark). Press **Enter**, then pick on each side of the original line and there will be the two lines for the outlet. Delete the extra centre line (Figure 3).

5. **Window symbol.** This is the simplest style for drawing windows, though there are others. Draw a 6” horizontal line. Offset this line the length you want the window to be, using the Offset command; enter the distance in feet or inches. To draw the centre line of the window between the offset lines you have just drawn, type **L** for line, type **MID** for the middle of the line, pick the middle of one of your lines, and then type **MID** again and pick the midpoint of the other line.
6. To stretch the window either longer or shorter, type **STRETCH** and make a pick window around one end of the window; be sure to pick the endpiece and a bit of the centre line of the window. Press **Enter** after the selection and pick the intersection of the centre line and the end of the window. Press **Enter** and pull the pieces in the direction and in the amount you want to go. Then let the mouse drop the end of the window at the desired length.

7. Save the drawing as *myblocks.dwg*.

**Commands to Use/Learn**

- Centre point
- Offset
- Circle
- Osnap
- Copy
- Print / Plot
- Dimstyle
- Snap
- Grid
- Text
- Limits
- Trim
- Line
- Units
- Midpoint
- Zoom
- Move
Procedure

1. Open up a new file in your CAD software.
2. Set units to “Architectural” (Figure 2). As in the included images at the end of the activity.
3. Set your Grid to 2” and your Snap to 6”.
4. Limits: set up 0,0,0 and upper right corner 32’,24’
5. Units (Figure 4), Print / Plot (Figure 5), and Dimstyle (Figure 6) MUST be set to the values in the screen captures. Look at the figures and set them carefully in AutoCAD. All other default settings are satisfactory, though they can be changed if required.

Units Window

Set “Type” to “Architectural” (Figure 4).
Print/Plot Window

Use the print/plot window when you want to print your drawing. In this case, the plot is set to save to a PDF file. Otherwise, you can print to your local or network printer by selecting it in the “Printer/plotter” name list. Do not forget to set the orientation to “Landscape” and the “What to plot:” to “Limits” to plot to a standard letter-size paper (Figure 5).

Figure 5
Dimstyle Window

Set “Unit format” to Architectural in the Primary Units tab (Figure 6). Also go to the Fit tab and change the “Use overall scale of” to 32 to reflect the fact you have scaled up your limits to 32’ by 24’ from the 11” by 8.5” used in the Draw Your Border activity.

![Dimstyle Window](image)

**Figure 6**

6. When you are finished, save the file. You will be able to open this file later for other assignments to use the symbols. To save, select “Save As” from either the Application Menu or the Quick Access toolbar in the upper-left corner of the program (Figure 7). When the “Save Drawing As” window opens up, navigate to the folder where you save your work. Save your work as “myblocks.dwg” as shown (Figure 8).
Figure 7

Figure 8
Drawing a Simple Building

Description
In this activity the teacher will give an introduction to the principles of designing and drawing a simple structure. This activity is an opportunity for students to think through the basic practical and aesthetic considerations of the design process.

Lesson Objectives
The student will be able to:

- Identify and itemize design characteristics
- Sketch out the ideas on paper in near scale
- Draw out a simple building based on the defined space limitations
- Design a simple building using the predefined template created in the Symbols and Standards activity, or design a simple building from scratch
- Plot to fit the drawing to letter-sized paper

Assumptions
The student will:

- Know how to login to a computer and open up the software
- Know how to save the drawing as a named file in their own directory
- Have been introduced to the basic drawing commands for drawing 2D objects

Terminology
Border lines: thick, dark lines used to create a solid border around a blank page.

Cardinal direction: from the origin of any starting point, a line can be drawn in the cardinal directions: North, South, East, and West (Figure 1). In AutoCAD, East is the 0° (zero) direction, North is the 90° direction, West is the 180° direction, and South is the 270° direction. One can draw angled lines in negative directions as well. For example, –90° is the same as 270°.
Design: a plan or drawing produced to show the look and function or workings of a building, garment, or other object before it is built or made.

Floor plan: a scale drawing of the arrangement of a building.

Plot: to set up your drawing to print to a file or paper.

Polyline: a continuous line that is made up of connected line segments.

Scale: a drawing that is enlarged or reduced from its original size, usually expressed as a fraction in imperial measurement (e.g., $\frac{1}{16}$ to 1') and as a ratio in metric measurement (e.g., 1:50, where 1 mm in the drawing equates to 50 mm in the actual work).

Spline: a linetype that draws curved lines in non-specific curves from point to point. They are made up of arcs that go through small, continuous points along the line until the spline is finished. They are often used for topography maps where specific elevations and their locations are known and a curved line can connect points on the same elevation.

Estimated Time

4 hours

Recommended Number of Students

20, based on *BC Technology Educators' Best Practice Guide*

Facilities

Computer lab installed with CAD software (Google SketchUp, AutoCAD, Cadopia, Vector works, etc.) and Internet access

Tools

Projector with computer and speakers installed with CAD software
**Materials**

Student activity with instructions

**Resources**

Instructional video for teacher and students to follow:

- **12.1:** Drawing the External Walls of a Building
- **12.2:*** Placing Architectural Blocks into a Drawing
- **12.3:** Scaling Your Border and Dimensioning a Floor Plan

**Architectural and design journals:**

**The Frank Lloyd Wright Foundation**  
http://www.franklloydwright.org/

**Design Boom Architecture**  
http://www.designboom.com/architecture/

**A/N Blog (Architects Newspaper)**  
http://blog.archpaper.com/2016/01/87th-birthday-frank-gehry-embraces-yacht-life-gehry-designed-sailboat/#.VpPLA0_mjU8

**Architecture and Design**  

**Teacher-led Activity**

The intent of the teacher-led activity is to demonstrate opening the previous *myblocks.dwg* file and renaming it as *mybuilding.dwg*. This imports the core settings from the Symbols and Standards activity (window, door, wall, switch, receptacle, light), which are the same for this activity. The teacher will demonstrate:

- Projecting the completed drawing
- Using the function keys to turn on and off the Snap, Grid, and Ortho dynamically
- Drawing lines that indicate the exterior of the building to a maximum size of 12’ × 12’
- Using the Offset command to offset the exterior walls to the inside for a distance of 6” as per construction standards of BC
- Trimming off the intersections of the interior offset corner intersections
- Inserting one of the fixtures into the drawing to give an example of placement
- Setting the grid and snap to 1’ to draw the border lines 1’ within drawing limits (32’ by 24’)**
Teacher-led Extension Activities

A variety of artistic renderings of architectural plans may be used to communicate what a building is going to look like once it is built:

• One-, two-, and three-point perspectives give a range of views from a variety of angles.
• Elevations are straight-on views from all sides of a building, as it would look after it has been built.
• The best resource to understand these views is Google Images. Look at examples of “one-, two-, and three-point architectural perspectives” and “architectural elevations.” Present these to students as examples of artists’ and professional architects’ renderings. Landscape architecture is a whole field unto itself and example plans from the Internet can be presented.
• When developing a plan, ideas must be listed for the purpose of the building, its contents, the interior layout, windows, lighting, electrical outlets, and switches (e.g., you do not want a switch behind a door). A sketch on paper should have the fixtures placed roughly as they would be in the completed building.

Student Activity

Students will follow the Student Activity and draw their own small building, complete with border, inserted title block, and placed blocks.

Assessment

The student’s work will be assessed on a “done, not done” basis:

| Building ideation with a list of the building’s features, including all the required fixtures, windows, and doors | Done | Not Done |
| Sketch of the interior layout (scale is not important in the ideas phase) | |
| Exterior walls and interior walls placed and trimmed | |
| Switch and outlet fixtures placed appropriately | |
| Window(s) inside the walls | |
| Door placed in the wall | |

Extension Activities

Have students draw elevations, one- and two-point perspective, presentation, site plans and landscape architecture:

• In one-point perspective all horizontal and vertical lines remain as in the plan.
• In two-point perspective only the vertical lines are as in the plan.
• Elevations are the various side views of the plan and are taken directly from the plan, point for point.
Student Activity

Activity Description
Using the software, create the drawing and produce your own small building using the drawing set-up and the commands that have been demonstrated for you. An alternative is to open your myblocks.dwg and use its predefined state to transfer its settings into your new drawing. The units will be the same as they were in the myblocks.dwg and are architectural/imperial. See Figure 1 for an example of a finished drawing.

Generating ideas
In this activity you are limited to a building no more than 12' by 12'. You must create a list on paper or a text file of all the things you want inside the building. That includes all the fixtures, windows, and doors you drew in the Symbols and Standards drawing, and can also include other items such as sinks, a toilet, and counters you may want in the building as well. You then must sketch out on paper an approximation of your building with the things you want inside. Once your ideas are checked, you can then begin the CAD drawing.

What you must draw
You need to draw a complete building with a door, a window, at least one light fixture, light switch, and wall outlets placed 8' apart around the inside of the building. The window(s) and door should be placed in the CAD drawing so it “works” with the features you’ve previously listed and the use of your building.
Commands to Use/Learn

- Cardinal directions
- Circle
- Copy
- Dimstyle
- Grid
- Limits
- Line
- Linetype
- Midpoint
- Move
- Offset
- Polyline
- Print/plot
- Snap
- Spline
- Text
- Trim
- Units
- Zoom

Part 1: Starting Your Drawing

A. Starting with a New Drawing

To start a new drawing from scratch, follow the steps below:

1. Open up an imperial border template drawing in your CAD software.

2. Grid and Snap set-up: set both to 2'.

3. Limits set-up: 0,0,0 and upper right corner 32',24' are set at the command line by typing LIMITS and pressing enter to cycle through the choices to ensure they are correct.

4. Dimstyle, Units, and Print/Plot MUST be set to the values in the screen captures for architectural drawing:
   - Under Dimstyle, set “Unit format” to “Architectural” (Figure 2)
   - In the Units window, set “Type” to “Architectural” (Figure 3)

5. Look at Figures 2, 3, and 4 and apply all settings carefully in AutoCAD. All other Default settings are satisfactory, though they can be changed if required.

6. Save your drawing as mybuilding.dwg.
Design and Drafting—3D Modelling

Drawing a Simple Building (Architectural CAD)

Youth Explore Trades Skills

Figure 11—Dimstyle window

Figure 12—Units window
B. Starting with a Predefined Drawing

If you are using a previously created drawing as the starting point for this activity, follow the steps below:

1. Open your *myblocks.dwg*.
2. Resave this drawing as *mybuilding.dwg*.
3. Check that the drawing has the same start-up Units (Figure 3), Limits, and Dimstyle as in the *myblocks* drawing.
4. You will have all the blocks you made before in the Symbols and Standards activity and you may have to move them to the outer edges of the drawing space to make room for the actual building you will draw.

Part 2: Scaling the Title Block and Border

Type SCALE; then highlight the border and title block. Pick the bottom left corner of the title block. Enter the scale factor of 32, to match how big you changed the drawing limits. The border should now almost fit the limits of the drawing.
Part 3: Drawing the Building

1. Ensure that Snap and Grid are on and set to 1'.
2. Start at least 2' into the drawing space and draw a 12' by 12' box.
3. Type OFFSET and set it to 6". Press enter.
4. Offset all the walls inside the 6" and trim out the excess lines at the corners.
5. Copy the original blocks you made before to place them wherever you choose in the drawing. You may have to rotate them, but you should not have to scale them if you did the myblocks drawing correctly.
6. After placing the switch and light fixture blocks, type SPLINE. Start the line at the switch and click on all the light fixtures you placed before.
7. Type LINETYPE to open the Linetype Manager (Figure 4). You will see some linetypes already loaded, but not the dashed line. Click on Load and choose the dashed line from the selection set.
8. Select the completed polyline and type PROPERTIES. A dialogue box will open. Look for the linetype; because you already loaded the dashed line into your drawing, you can select it from the list and your line will change to a dashed line when you do. You must change it back to “continuous” if you wish to continue drawing with continuous lines.
9. Type DIM and select the lines you wish to dimension. Make sure the dimensions are outside the building. You should dimension the position of the door and the window as well.
10. Delete out of the drawing the extra blocks you are no longer using.
11. Save the drawing.
12. Plot/print the drawing. Refer to Figure 6.
Part 4: Printing Your Drawing

Print/Plot Window

When you want to print your drawing, you must type PLOT and make the choices indicated in Figure 6. In this case, the plot is set to save to a PDF file. Otherwise, you can print to your local or network printer by selecting it in the “Printer/plotter” name list. Do not forget to set the orientation to “Landscape” and the “What to plot:" drop-down selection to “Limits,” to plot to a standard letter-size paper.

![Print/plot window](image)

Figure 14—Print/plot window
Exploring SketchUp Make

Description
In this activity, the teacher will demonstrate how to open up a template in SketchUp Make; how to create and modify a 3D shape; and then how to import and modify items from the 3D Warehouse.

Lesson Objectives
The student will be able to:
• Open up a template
• Use basic 2D drawing tools
• Use 3D modelling tools
• Modify a 3D shape
• Import an item from the 3D Warehouse
• Modify items from the 3D Warehouse

Assumptions
The student will:
• Know how to login to a computer and open up the software
• Know how to save work

Terminology
3D Warehouse: an online distribution platform to share SketchUp models. Any person can post models to this website, including students, businesses, architects, etc. Any person can also download files posted to this site.

Floor plan: a scale drawing of the arrangement of a building.

Follow Me: a tool in SketchUp that allows you to draw a 2D path and select a 2D surface, and then pull the surface along the path to create a 3D shape.

Offset: a command that creates a copy of an entity (line, circle, etc.) a specified parallel distance away from the current object(s) selected.

Push/Pull: a tool in SketchUp that allows you to select a surface and push or pull it into 3D. You can also use this tool to push or pull a shape to create a negative space in a surface.
Scale: a drawing that is enlarged or reduced from its original size, usually expressed as a fraction in imperial measurement. The most common architect’s scale is ¼ inch to the foot, expressed as Scale ¼" = 1'-0". In metric measurement, scale is expressed as a ratio (e.g., 1:50, meaning 1 mm in the drawing equates to 50 mm in the actual work). The actual building measure would be multiplied by the scale factor.

SketchUp Make: 3D software originally developed by Google to assist in creating Google Earth. Google released the software for free to users and called it Google SketchUp. SketchUp was later purchased by Trimble, and is now software available for purchase, although it is free to teachers and students.

Template: a file in a specific unit of measurement with pre-set parameters that can possibly include layers, textures, material, blocks, etc.

Estimated Time
30 minutes

Recommended Number of Students
20, based on BC Technology Educators’ Best Practice Guide

Facilities
Computer lab installed with CAD software (SketchUp Make, AutoCAD, etc.)

Tools
Projector with computer and speakers, Internet access

Materials
Student activity with instructions

Resources
Instructional video for teacher and students to follow:
- 13.1: Exploring SketchUp Make

Teacher-led Activity
Use a computer with a projector and demonstrate the following:
- Open an imperial/inches SketchUp file
- Use 2D drawing and modification tools
- Use 3D drawing and modification tools
- Import items from the 3D Warehouse
- Modify items from the 3D Warehouse
**Student Activity**

Students will follow the video tutorial and the Student Activity “Setting Up Your Model Space” and will explore the SketchUp software.

**Extension Activity**

Have students draw a specific object, like a children's playground, a doghouse, etc.

**Assessment**

Students will show the teacher what they have created, before moving on to the Creating a Simple Architectural Structure activity.
Student Activity: Setting Up Your Model Space

Using the software, explore the 2D and 3D drawing and modification tools, including “importing objects from the 3D Warehouse.” The video to support the lesson is located under Resources.

Procedure

1. Open up your SketchUp Make software, and as the software loads watch tutorial video 13.1, “Exploring SketchUp Make.” Once the software has loaded, select a feet and inches template.

2. Once the drawing file is open, check out your toolbars. If your software does not display the same toolbars, go to the View tab, select Toolbars, then select whatever toolbars you wish to display.

3. Next explore the software as demonstrated in the video. Feel free to try out any icon in the toolbars.

4. Lastly, try to import an object from the 3D Warehouse. Then try to scale and rotate that object.

5. Show your instructor before moving on to the next activity.
Create a Simple Architectural Structure

Description
In this activity the teacher will demonstrate how to transform the 2D floor plan into a 3D structure, using the plan created in the Drawing of a Simple Building activity.

Lesson Objectives
The student will be able to:
- Open up a template
- Use basic 2D drawing tools to draw a floor plan
- Use 3D modelling tools to create walls, cut out for windows and doors, and create a roof
- Import an item from the 3D Warehouse
- Scale and rotate items from the 3D Warehouse
- Apply textures and colours

Assumptions
The student will:
- Know how to login to a computer and open up the software
- Know how to save their work
- Know the skills learned in the Exploring SketchUp Make activity

Terminology
3D Warehouse: an online distribution platform to share SketchUp models. Any person can post models to this website, including students, businesses, architects, etc. Any person can also download files posted to this site.

Eave: the part of a roof that meets or overhangs the walls of a building.

Fascia: a flat board that covers the end of the rafters, where the roof meets the eave.

Floor plan: a scale drawing of the arrangement of a building.

Follow Me: a tool in SketchUp that allows you to draw a 2D path and select a 2D surface, and then pull the surface along the path to create a 3D shape.

Gable end: the part of a wall that encloses the end of a pitched roof.

Offset: a command that creates a copy of an entity (line, circle, etc.) a specified parallel distance away from the current object(s) selected.
Push/Pull: a tool in SketchUp that allows you to select a surface and push or pull it into 3D. You can also use this tool to push or pull a shape to create a negative space in a surface.

Scale: a drawing that is enlarged or reduced from its original size, usually expressed as a fraction in imperial measurement. The most common architect’s scale is ¼ inch to the foot, expressed as Scale ¼" = 1'-0". In metric measurement, scale is expressed as a ratio (e.g., 1:50, meaning 1 mm in the drawing equates to 50 mm in the actual work). The actual building measure would be multiplied by the scale factor.

SketchUp Make: 3D software originally developed by Google to assist in creating Google Earth. Google released the software for free to users and called it Google SketchUp. SketchUp was later purchased by Trimble, and is now software available for purchase, although it is free to teachers and students.

Template: a file in a specific unit of measurement with pre-set parameters that can possibly include layers, textures, material, blocks, etc.

Estimated Time
30 minutes

Recommended Number of Students
20, based on BC Technology Educators’ Best Practice Guide

Facilities
Computer lab installed with CAD software (SketchUp Make, AutoCAD, etc.)

Tools
Projector with computer and speakers, Internet access

Materials
Student activity with instructions

Resources
Instructional video for teacher and students to follow:
  • 14.1 Creating a Simple Architectural Structure (Part 1)
  • 14.2 Creating a Simple Architectural Structure (Part 2)
  • 14.3 Creating a Simple Architectural Structure (Part 3)
  • 14.4 Creating a Simple Architectural Structure (Part 4)
**Teacher-led Activity**

Use a computer with a projector and demonstrate the following:

- Open an imperial/inches SketchUp file
- Draw a 2D floor plan
- Create walls and frame in the door and windows
- Apply texture to the inside walls and floor
- Import items from the 3D Warehouse to suite the purpose of the shed
- Apply texture to the outer walls
- Import and scale windows and a door
- Insert the windows and the door
- Offset roof line to create overhang
- Create a roof
- Apply textures to the roof and the eave
- Optional: add other features to the exterior of the shed, as well as the surrounding space around the shed

**Student Activity**

Students will follow the video tutorials and the Student Activity “Creating a Simple Architectural Structure” to create a 3D shed.

**Extension Activity**

Have students create a more involved floor plan, then complete the remaining structure from that plan (Figure 1).

![Figure 15—Example of a more involved floor plan](image)

**Assessment**

Students will show the teacher what they have created, before moving on to Creating a Simple Architectural Structure activity.
Student Activity: Creating a Simple Architectural Structure

Using the software, transform your 2D floor plan into a 3D shed. Videos are located under Resources to support the lesson.

Procedure

1. Open up your SketchUp Make software, and as the software loads watch the Part 1 tutorial video. Once the software has loaded, select a feet and inches template.
2. Once the drawing file is open, check out your toolbars. If your software does not display the same toolbar, go to the View tab, select Toolbars, and then select the toolbars you wish to display.
3. Next, draw your floor plan as shown in the video. Don’t forget to include the windows and doors.
4. Use the Push/Pull button to pull your walls to a height of 8’.
5. Frame the bottom of the windows so they are 3’ from the ground.
6. Complete the door so it is 7'4" high, and then align the top of the windows to match.
7. Continue to fill in the surfaces and delete extraneous lines until your base structure is complete.
8. Watch the Part 2 tutorial video; then apply textures and personalize the inside of your shed. What is your shed’s purpose? A tiny home? A reading nook? A potting shed? A motorcycle garage? Give your shed a purpose and get creative with your textures and features inside!
9. Once the inside is complete, watch the Part 3 tutorial video. Then go to the 3D Warehouse and pick out your windows and door.
10. Insert the windows and door into your model and scale them accordingly.
11. Move the windows and door into place, and be sure to line them up perfectly with the space provided.
12. Draw the line wrapping around your structure at the 6” mark (unless you know the building code for your area, and the requirement for exposed foundation; then use that measurement).
13. Apply a concrete texture to the bottom 6” of your structure; then select a siding material to apply to the rest of the walls. You can also modify the size and colour of the texture by clicking on the edit tab and making whatever changes you wish.
14. Watch the Part 4 tutorial video. Decide what type of roof you’d like to make. The tutorial shows how to make a standard pitch roof, with the gable ends at the front and back of the shed.

15. Offset your top outer rectangle by 6”; then pull that top surface by 6”.

16. As in the video, draw a triangle on either end of the house, with a 2’ peak.

17. To create the ridge of the roof, join the two triangles and enclose the roof structure.

18. Draw two offset lines of your peak on either end, by a distance of 6”, and push the unwanted parts away.

19. Apply your selected roof texture to the roof, the fascia, and the eave.

20. Your shed is complete (see example in Figure 2). Add any additional features including signs on the exterior, a chimney, landscaping, etc.

21. Save your work.

22. Show your instructor before creating the cardboard model of your shed in the next activity.

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Figure 16—Sample completed shed design
Modelling Your Structure

Description
In this activity, the teacher will demonstrate how to transform the digital 3D model you created in the Create a Simple Architecture Structure activity into a 3D cardboard model.

Lesson Objectives
The student will be able to:

• Change the printer set-up
• Change the camera view
• Select different camera views
• Change the scale on the print preview window
• Print four views of a shed
• Cut and glue the four views to cardboard
• Assemble the shed with a removable roof and special features inside, displayed with name and scale

Assumptions
The student will:

• Know how to login to a computer and open up the software
• Know how to save work
• Know the skills learned in the Exploring SketchUp Make and Creating a Simple Architectural Structure activities

Terminology
Scale: a drawing that is enlarged or reduced from its original size, usually expressed as a fraction in imperial measurement. The most common architect’s scale is ¼ inch to the foot, expressed as Scale ¼" = 1'-0". In metric measurement, scale is expressed as a ratio (e.g., 1:50, meaning 1 mm in the drawing equates to 50 mm in the actual work). The actual building measure would be multiplied by the scale factor.

SketchUp Make: 3D software originally developed by Google to assist in creating Google Earth. Google released the software for free to users and called it Google SketchUp. SketchUp was later purchased by Trimble, and is now software available for purchase, although it is free to teachers and students.
Estimated Time
3 hours

Recommended Number of Students
20, based on BC Technology Educators’ Best Practice Guide

Facilities
Computer lab installed with CAD software (SketchUp Make, AutoCAD, etc.)

Tools
Projector with computer and speakers, Internet access, utility knife, cutting mats, rulers, hot glue gun

Materials
• Student activity with instructions
• Cardboard
• Stick glue
• Hot glue

Resources
Instructional video for teacher and students to follow:
• 15.1: Modelling Your Structure

Teacher-led Activity
Use a computer with a projector and demonstrate the following:
• Make changes to printer set-up
• Change camera views
• Change the scale on the Print Preview window to suit paper size
• Print front, right, back, and left side views of the shed
• Cut out the views and glue them to cardboard
• Create a removable cardboard roof
• Draw and decorate the interior of the shed
• Glue the four walls together, including any special features or furniture for the interior
• Glue the shed (with removable roof) to a cardboard base
**Student Activity**

Students will follow the video tutorial and the Student Activity “Modelling a Simple Architectural Structure” to create a cardboard model of their shed.

**Extension Activity**

Have students create a more involved floor plan, then complete the remaining structure from that plan (Figure 1).

![Figure 17—Example of a more involved floor plan](image)

Alternatively, have students 3D-print or CNC a model of their floor plan. See Extension Activity: Prototyping Your Model Using 3D Printing and CNC Technology.

**Assessment**

Students will hand in their cardboard model for marking.

Full marks will be awarded if the structure is neat and matches the indicated scale, and if textures have been applied to the interior walls, floor, exterior walls, windows, door, roof, fascia, and eave. Bonus marks will be awarded if the student has created additional features for the interior or exterior.
Student Activity:
Modelling a Simple Architectural Structure

Using the software, transform your digital shed model into a cardboard model (see video 15.1: Modelling Your Structure*).

Procedure

1. Open up your SketchUp Make software, and as the software loads watch the tutorial video (“Modelling Your Structure”). Once the software has loaded, open your shed file.

2. Next, set up your printer. Select the landscape orientation for your paper and select the correct printer (ask your instructor if you do not know which printer to select).

3. To get accurate scale views, change your camera perspective to parallel projection, as shown in the video.

4. Next, select the camera standard view FRONT.

5. Zoom in to your shed so it fits fully and is centred on your screen.

6. Open the Print Preview window and set the scale up as follows (Figure 2) for letter-sized paper.
7. Check your Preview. If your shed fits nicely on the page, then go ahead and print.

8. Repeat steps 4–7 for the remaining three views (right, left, back).

9. Cut out all of your views and glue them to cardboard using stick glue.

10. Cut out the cardboard, following the outline of your views. Once you cut them out, you should have four pieces: front, right side, back and left side.

11. Complete the interior of the shed by drawing any special features and colouring the walls.

12. SketchUp does not provide an adequate view of the roof for printing. SketchUp can create a bird’s-eye view, but if you were to print that and then cut it out with cardboard, the roof pieces would be too short, because you would be printing the run length of the roof instead of the slope length (Figure 3).

![Figure 19](image19.png)

13. In order to create your roof, you will have to measure the run length from the front view cut-out, and the roof length from the side view cut-out (Figures 2 and 3). Then, lay out those two rectangles on the cardboard and cut them out. You can colour or draw your roof material details at this point. Hot glue the ridgeline to create a one-piece roof. Keep the roof detached from your shed, like a lid.

![Figure 20](image20.png)
14. Glue your four shed walls together using hot glue; then hot glue the frame to a cardboard base.

15. Create any additional interior features out of cardboard or other recycled modelling material.

16. Create any additional exterior features out of cardboard or other recycled modelling material.

17. Write your name and your shed scale on the cardboard base. Then give your project a once over before handing it in to your teacher. Remember to keep your roof detached so your instructor can see inside your structure. If you used the same scale as the example, then the scale should read = 1:24, meaning 1 inch of your model equates to 24 inches in real life.
Prototyping Your Model Using 3D Printing and CNC Technology

Description
In this activity, the teacher will discuss and demonstrate possible prototyping options using 3D printing and CNC technology.

Lesson Objectives
The student will be able to:

- Know the file formats necessary for 3D printing and CNC
- Save a file into the appropriate file formats
- Understand 3D printing as an additive technology
- Understand CNC as a subtractive technology
- Send a file for 3D printing or CNC cutting
- Understand the function of G-Code and how it relates to the operation of a CNC

Assumptions
The student will:

- Know how to login to a computer and open up the software
- Know how to save their work
- Know the skills learned in the following activities:
  - Exploring SketchUp Make
  - Creating a Simple Architectural Structure
  - Modelling Your Structure

Terminology

3D printing: a rapid prototyping process that creates a physical object from a digital 3D model, typically by laying down many successive layers of material.

Additive technology: a technology that creates prototypes by adding material.

CAM software: specialized computer aided manufacturing software that controls machine tools and related machinery in the manufacturing of workpieces. In this activity, CAM software refers to software that controls a CNC router.

CNC machining: a process used in the manufacturing sector that involves the use of Computer Numerical Control machines.
**CNC router**: a router that is controlled by a computer and used for rapid prototyping, typically by removing material with a cutting bit.

**G-Code**: a coding language that tells computer numeric machines how to make something.

**Subtractive technology**: a technology that creates prototypes by removing material.

**Estimated Time**
1–5 hours (this will depend on what technology is available, and the complexity of the model being prototyped)

**Recommended Number of Students**
20, based on *BC Technology Educators’ Best Practice Guide*

**Facilities**
Computer lab installed with CAD and CAM software (SketchUp Make, AutoCAD, GibbsCAM, Mastercam, etc.), as well as a CNC router and/or 3D printer

**Tools**
Projector with computer and speakers, Internet access, 3D printer, CNC router

**Materials**
- Student Activity “Prototyping Your Model Using 3D Printing and CNC Technology”
- Internet access
- Material for 3D printer or CNC router

**Resources**
Thingiverse
[www.thingiverse.com](http://www.thingiverse.com)

Extension Warehouse
[https://extensions.sketchup.com](https://extensions.sketchup.com)
**Teacher-led Activity**

Use a computer with a projector and demonstrate the following:

- Introduction to rapid prototyping: 3D printing and CNC, additive and subtractive technologies
- What .stl. and .dxf file extensions are
- How to save your SketchUp model or CAD file as .stl or .dxf file extensions
- Ways to 3D print your .stl file
- Ways to CNC your .dxf file
- The function of G-Code in CNC

**Student Activity**

Students will 3D print their shed or CNC the floor plan of their shed, depending on availability of prototyping equipment.

**Assessment**

Students will self-assess their prototype, including their new understanding of subtractive and additive technology, as well as the use of G-Code.

**The goal of self-assessment:**
Can the student recognize personal strengths and weaknesses over time and become a stronger, more independent learner?

**Some self-assessment critical questions for students:**

- What new information have I learned? How will I act on this information—accept, reject, or modify?
- What new knowledge and understanding have I gained from this activity?
- What is the new systematic process I have learned, and have I completely investigated this topic, or is there room for further investigation?
- What direction do I want to take for future investigation?
- How did my prototype turn out? Using my new understanding of prototyping, how could I improve my prototype? Does it involve a change in the modelling process, tooling, etc.?

**Some self-assessment strategies for students:**

- Use interaction with and feedback from teachers and peers to guide own learning process.
- Monitor the gathered information and new knowledge, and assess for gaps or weaknesses.
- Seek appropriate help when it is needed.
Introduction to rapid prototyping: 3D printing and CNC, additive and subtractive technologies

Rapid prototyping technologies are rampant in industry. There are two main types of rapid prototyping technologies: additive and subtractive technologies.

Additive technologies, such as a 3D printer, are those that add or build material to create a prototype. There are many different types of 3D printers, but those most commonly found in an educational environment use Fused Deposition Modelling (FDM). An FDM printer is like a hot glue gun operated by a robot that only speaks in x, y, and z coordinates. A model is created by adding layer upon layer of plastic until the model is complete. Essentially, the build material melts, hardens, and fuses layer upon layer. Because you start with a fresh slate and add material to create your model, this is an additive technology. The most common materials to print in an educational setting are ABS and PLA plastics.

Subtractive technologies, such as a Computer Numerical Control (CNC) machine, are those that remove material to create a prototype. The CNC machine most commonly found in an educational setting is the CNC router. The CNC router, more or less, is controlled by a robot that only speaks in x, y, and z coordinates. It creates a model by removing layer after layer of modelling material until the model is complete. Because you start with a piece of modelling material that you cut away to create your model, this is a subtractive technology. In an educational setting the CNC router most commonly cuts wood, plastic, and Styrofoam.

What are .stl and .dxf file extensions?
In order to use a 3D printer or CNC router to create your model, you need to save your file with a specific file extension. Typically, 3D printing software requires .stl files and CNC router software requires .dxf files.

An .stl file takes a 3D object and slices it into many layers, then translates that information into x, y, and z coordinates. This type of file can be imported into brand-specific 3D printing software, where the user can determine how big, how many, and what quality of print they’d like their model. Once these factors are determined, the 3D printing software sends a machine-specific file to the printer and you can begin your print.

A .dxf file can be 2D or 3D; however, a CNC router typically found in an educational setting will not be able to create a model of your shed with windows and roof. The CNC router typically found in schools has three axes. However, you would require a five-axis machine in order to cut out your shed with windows and a roof. A three-axis CNC router could easily create a model of your floor plan with walls, as long as your walls are 90 degrees to the CNC table. This machine cannot come in from the side and cut out windows, doors, or overhang.
So, you can use your SketchUp shed file (as long as you return your file to walls only) or your CAD floor plan file (walls only, no light fixtures or windows, etc.). You can save either file as a 2D .dxf, then import it into a CAM software like GibbsCAM or Mastercam, where you can create toolpaths for the CNC to follow to cut out your floor plan. At this point, you could save your machine-specific file, and then run the code on your CNC router.

**How to save your SketchUp model or CAD file as those file extensions**

In SketchUp and CAD, it is easy to save your file as a .dxf. Remember, you only want to save the file that has your walls, but no other extraneous details. You simply go to File, Export. When you save, select the .dxf file type (Figure 1). The steps are almost identical for SketchUp and AutoCAD, except SketchUp asks you to specify 2D or 3D before it allows you to save as .dxf.

![Figure 21](image1.jpg)

In SketchUp, you cannot easily save your file as an .stl. You first must download an .stl converter, located in the extension warehouse:

https://extensions.sketchup.com/en/content/sketchup-stl

![Figure 22](image2.jpg)
Once you install the .stl converter, you will be able to save your shed as an stl as shown in Figure 2: File, Export STL. If you have added trees or other items, you may want to remove them so only your shed remains in your SketchUp file before you do the file conversion.

**Ways to 3D print your .stl file or CNC cut your .dxf file**

If your school does not have a 3D printer or a CNC router and you would like to 3D print or model your shed, there are many options. Perhaps another school in your district or a nearby college/university or library owns a 3D printer or a CNC router and would print or cut the file for you. Ask your instructor for suggestions. If not, there are online companies that will 3D print or cut and ship your model to you.

**The function of G-Code in CNC**

G-code is a language used by people to tell CNC machines how to make something. The “how” is defined by instructions on where to move, how fast to move, and what path to move. The CAM software, like Mastercam and GibbsCAM, creates the G-Code from your .dxf file. In the code, the common parameters are defined with the letter G, hence G-Code.

Examples of G-Code:

**G0 X1 Y1** → G0 is the axis position with rapid movement; therefore, the CNC cutter moves quickly to (1,1).

**G0 Z-0.1** → G0 is the axis position with rapid movement; therefore the CNC cutter moves down quickly to a distance of 0.1 above your material.

**G1 Z-4 F10** → G1 is a controlled feed movement, meaning the CNC cutter moves down at a feed speed of 10 and cuts into your material a distance of 4.

**G1 X2 Y4** → G1 is a controlled feed movement, meaning the CNC cutter continues to cut at a feed speed of 10, and cuts over to location (2,4).

G-Code also uses other letters, like M and T; however, G is the most prominent letter in the code. This coding language is basic yet tedious, and although it is possible to write the code and send it to the CNC, it is highly uncommon. Because we have software that creates a more accurate and machine-specific G-Code, people no longer feel the need to write G-Code. However, it is important to have an understanding of G-Code. If a machine makes a mistake, for example, we can scroll through the code, determine where the mistake was made, and modify the code to reflect the correction.
3D Modelling a Set of Stairs

Description
In this activity students will begin by drawing a set of stairs in 2D similar to the one drawn previously using the isometric view. Then they will extrude the drawing to create a three-dimensional rendering. The intent of this activity is to learn how to draw a 2D sketch using the drawing tools and how the constraints and dimensions tools affect how and what you draw. Drawing methods will vary slightly in each software package, but the overall concepts are the same. As this activity does not necessarily have to follow the previous CAD activities under Mechanical CAD, the student may have less knowledge of the terminology, the drawing tools and how to use them.

Lesson Objectives
The student will be able to:
- Create a 2D sketch using constraints and dimensions
- Use various tools to edit the 2D sketch
- Extrude a 2D sketch

Assumptions
The student will:
- Know how to login to a computer and open up the software
- Understand the working environment of the software and how to navigate it
- Have already created a simple 2D sketch in the software (to be repeated as part of this activity)

Terminology
Note: terms with an asterisk (*) are copyright the Autodesk Knowledge Network, licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Licence (CC BY NC SA 3.0) https://creativecommons.org/licenses/by-sa/3.0/deed.en

Application button: the icon in the top left corner of the screen that contains New, Open, Save, etc.

Assembly constraints*: rules that determine how parts in an assembly are placed relative to other parts in the assembly. Constraints remove degrees of freedom. Assembly constraints include angle, flush, mate, and tangent. Constraints may be placed between faces of features, part edges, points, inferred axes, and part work features such as planes, axes, and points.
**Assembly modelling**: two or more components (parts or subassemblies) considered as a single model. An assembly typically includes multiple components positioned absolutely and relatively (as required) with constraints that define both size and position. Assembly components may include features defined in place in the assembly. Mass and material properties may be inherited from individual part files.

**Browser**: sometimes called the *model tree*, is the graphical hierarchy showing relationships between geometric elements in parts, assemblies, and drawings. Icons represent sketches, features, constraints, or attributes for each model. Objects are shown in the browser in the order in which they were created. Objects may also be edited, renamed, added, deleted, copied, and moved to a different location in the browser.

**Constraints**: rules that govern the position, slope, tangency, dimensions, and relationships among sketch geometry or the relative position between parts in an assembly. Geometric constraints control the shapes and relationships among sketch elements or assembly components. Dimensional constraints control size. Applying constraints removes degrees of freedom.

**Drawing**: a 2D representation of a part or assembly. The drawing file type has an .idw extension.

**Extrude**: a feature created by adding depth to a sketched profile. Feature shape is controlled by profile shape, extrusion extent, and taper angle.

**Fully constrained**: when a 2D sketch or 3D part has had all the degrees of freedom removed and it cannot be freely moved anymore.

**Graphics window**: the active modelling area in which sketches, constraints, features, parts, and assemblies are created and edited. In the Graphics window, models can be rotated, zoomed in and out, and view characteristics such as colour, material, and light defined.

**Hard snap**: snap function represented by a green dot that appears when snapping to the endpoint of a sketch line. A hard snap is permanent and cannot be moved.

**Home view**: an isometric view of your model. When the Home button on the ViewCube is pressed, it zooms in and re-oriënts the model in the isometric view in the Graphics window.

**Marking menu**: when you right mouse click in the Graphics window in various modes (sketch, 3D model) a menu comes up with environment-specific command options arranged in a radial, rather than linear, display.

**Navigation bar**: a toolbar containing various tools to move or view your 2D sketch or 3D part in the Graphics window.

**Origin**: the point where the x, y, and z planes or axes intersect.

**Part**: a group of features and faces that have been combined to create a closed volume that is represented as a 3D object.

**Part modelling environment**: the environment where you create sketches and by using different commands eventually create a 3D part. In part modelling, you create sketches, use feature commands to create three-dimensional features, and then combine the features to create parts.
Ribbon: the palette that extends across the top of the Inventor interface and contains multiple tabs for convenient tool access.

Shell*: a parametric feature used most frequently for cast or moulded parts. From a specified face, material is removed from the part, leaving a cavity with walls of a specified thickness. Shells usually have walls of uniform thickness, but individual faces can be selected and their thickness specified. Shell walls can be offset to the inside, outside, or both sides of the part, relative to the original part surfaces.

Sketch*: consists of the sketch plane, a coordinate system, 2D curves, and the dimensions and constraints applied to the curves. A sketch may also incorporate construction geometry or reference geometry. Sketches are used to define feature profiles and paths.

Sketch environment*: consists of a sketch and sketch commands. The commands control the sketch grid and draw lines, splines, circles, ellipses, arcs, rectangles, polygons, or points.

Sketch plane: a planar face or work plane on which the current sketch is created.

Soft snap: snap function represented by a yellow dot that is not constrained, and therefore can be moved.

Status bar*: a display across the bottom of the active window that indicates the next action that the active command requires. When a 2D sketch or 3D sketch is active, the status bar for sketch displays commands specific to the sketch environment.

STEP file*: an international format developed to overcome some of the limitations of current data conversion standards. Files created in other CAD systems can be converted to STEP format and imported into Autodesk Inventor.

ViewCube: an interface on the Graphics window that helps switch between standard (front, side, top, etc.) views and isometric views of the model.

Work plane: the xy (front view), xz (top view), and yz (side view) planes. Sketches and 3D objects are drawn on these planes.

Estimated Time

45–60 minutes

Recommended Number of Students

20, based on BC Technology Educators’ Best Practice Guide

Facilities

Computer lab installed with 3D modelling software (Autodesk Inventor, PTC Creo Parametric, SolidWorks, etc.)

Tools

Projector with computer and speakers, Internet access
3D Modelling a Set of Stairs

**Materials**
Handout for students with instructions

**Resources**
Instructional video for teacher and students to follow (Inventor 2013):
- 11.1: Constraining and Dimensioning 2D Sketches
- 11.2: Drawing Your Stairs
- 11.3: Extruding Your Stairs

**Teacher-led Activity**
Use a computer with a projector and demonstrate the following:
1. Open the program and explain the environment (Browser, Ribbon, ViewCube, Navigation bar, Application menu).
2. Show how to navigate in the sketch environment or part modelling environment using the mouse (scroll left/right, zoom in/out, pan, orbit), the ViewCube, and Navigation bar tools (Navigation Wheel, Zoom, Pan, Orbit).
3. Start a part in imperial or metric.
4. Create a 2D sketch in the sketch environment.
5. Extrude a 2D sketch into 3D in the part modelling environment.
6. Modify a 2D sketch after it has been created in the sketch environment.
7. Modify a 3D part after it has been created in the part modelling environment

**Student Activity**
Students will follow the Student Activity “Drawing 3D Stairs” and/or the video tutorials to complete the assignment.

**Assessment**
Students will show the teacher their completed assignments. The teacher can have the assignment printed out or look at it on the computer screen. If the student does not produce exactly what was shown, then an associated mark based on errors can be derived.
Student Activity: Prototyping Your Model Using 3D Printing and CNC Technology

Using the software to learn basic 2D sketch skills, you are going to draw a set of stairs and then extrude them, rendering them as a three-dimensional image (Figure 6).

1. Open a new part from the application menu or from the get started tab on the ribbon (Figure 1).

![Image of software interface](image-url)
2. Next create a 2D sketch and highlight the xy plane (front plane, Figure 2). The program will now enter into the sketch environment.

![Figure 24]

3. Draw the stairs as shown (Figure 3). The steps will have a 2” rise and a 2” run. The total height of the stairs will be 10” and the total depth will be 10” as well.

![Figure 25]
4. Dimension the entire drawing so it is fully constrained (Figure 4). In the lower right corner of the status bar it will tell you how many more dimensions you need to fully constrain it.

5. Once the sketch has been fully constrained, click “Finish Sketch” on the right side of the sketch ribbon to exit the sketch environment.

6. Now select “Extrude” from the 3D model ribbon and select inside the stairs. The stairs will extrude into 3D. In the “Extrude” dialog box, change the depth of the extrusion to 10” (Figure 5). Click OK to finish the extrusion.
7. Your model should now be complete and the stairs should look like the ones in Figure 6.
Drawing and Assembling

Description
In this activity the six sides of a die will be drawn and then assembled together. The intent is to understand how constraints are used to “lock” individual parts together to form an assembly.

Lesson Objectives
The student will be able to:
- Create the six sides of a die
- Draw 2D sketches using constraints and dimensions
- Use various tools to edit the 2D sketch (trim, mirror, offset, rotate)
- Extrude a 2D sketch
- Draw a second 2D sketch and extrude it on the face of an already extruded 2D sketch
- Assemble parts into an assembly

Assumptions
The student will:
- Know how to login to a computer and open up the software
- Understand the working environment of the software and how to navigate it
- Have already created a simple 2D sketch in the software
- Have extruded a 2D sketch into a 3D part in the part-modelling environment

Terminology
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Application button: the icon in the top left corner of the screen that contains New, Open, Save, etc.

Assembly constraints*: rules that determine how parts in an assembly are placed relative to other parts in the assembly. Constraints remove degrees of freedom. Assembly constraints include angle, flush, mate, and tangent. Constraints may be placed between faces of features, part edges, points, inferred axes, and part work features such as planes, axes, and points.
Assembly modelling*: two or more components (parts or subassemblies) considered as a single model. An assembly typically includes multiple components positioned absolutely and relatively (as required) with constraints that define both size and position. Assembly components may include features defined in place in the assembly. Mass and material properties may be inherited from individual part files.

Browser*: sometimes called the model tree, is the graphical hierarchy showing relationships between geometric elements in parts, assemblies, and drawings. Icons represent sketches, features, constraints, or attributes for each model. Objects are shown in the browser in the order in which they were created. Objects may also be edited, renamed, added, deleted, copied, and moved to a different location in the browser.

Constraints*: rules that govern the position, slope, tangency, dimensions, and relationships among sketch geometry or the relative position between parts in an assembly. Geometric constraints control the shapes and relationships among sketch elements or assembly components. Dimensional constraints control size. Applying constraints removes degrees of freedom.

Drawing: a 2D representation of a part or assembly. The drawing file type has an .idw extension.

Extrude*: a feature created by adding depth to a sketched profile. Feature shape is controlled by profile shape, extrusion extent, and taper angle.

Fully constrained: when a 2D sketch or 3D part has had all the degrees of freedom removed and it cannot be freely moved anymore.

Graphics window*: the active modelling area in which sketches, constraints, features, parts, and assemblies are created and edited. In the Graphics window, models can be rotated, zoomed in and out, and view characteristics such as colour, material, and light defined.

Hard snap: snap function represented by a green dot that appears when snapping to the endpoint of a sketch line. A hard snap is permanent and cannot be moved.

Home view: an isometric view of your model. When the Home button on the ViewCube is pressed, it zooms in and re-orient the model in the isometric view in the Graphics window.

Kerf: a cut or incision (groove, notch, channel or slit) made in any material by a cutting tool such as a saw, axe or cutting torch.

Marking menu: when you right mouse click in the Graphics window in various modes (sketch, 3D model) a menu comes up with environment-specific command options arranged in a radial, rather than linear, display.

Navigation bar: a toolbar containing various tools to move or view your 2D sketch or 3D part in the Graphics window.

Origin: the point where the x, y, and z planes or axes intersect.

Part: a group of features and faces that have been combined to create a closed volume that is represented as a 3D object.
Part modelling environment*: the environment where you create sketches and by using different commands eventually create a 3D part. In part modelling, you create sketches, use feature commands to create three-dimensional features, and then combine the features to create parts.

Ribbon: the palette that extends across the top of the Inventor interface and contains multiple tabs for convenient tool access.

Shell*: a parametric feature used most frequently for cast or moulded parts. From a specified face, material is removed from the part, leaving a cavity with walls of a specified thickness. Shells usually have walls of uniform thickness, but individual faces can be selected and their thickness specified. Shell walls can be offset to the inside, outside, or both sides of the part, relative to the original part surfaces.

Sketch*: consists of the sketch plane, a coordinate system, 2D curves, and the dimensions and constraints applied to the curves. A sketch may also incorporate construction geometry or reference geometry. Sketches are used to define feature profiles and paths.

Sketch environment*: consists of a sketch and sketch commands. The commands control the sketch grid and draw lines, splines, circles, ellipses, arcs, rectangles, polygons, or points.

Sketch plane: a planar face or work plane on which the current sketch is created.

Soft snap: snap function represented by a yellow dot that is not constrained, and therefore can be moved.

Status bar*: a display across the bottom of the active window that indicates the next action that the active command requires. When a 2D sketch or 3D sketch is active, the status bar for sketch displays commands specific to the sketch environment.

STEP file*: an international format developed to overcome some of the limitations of current data conversion standards. Files created in other CAD systems can be converted to STEP format and imported into Autodesk Inventor.

ViewCube: an interface on the Graphics window that helps switch between standard (front, side, top, etc.) views and isometric views of the model.

Work plane: the xy (front view), xz (top view), and yz (side view) planes. Sketches and 3D objects are drawn on these planes.

Estimated Time
2–3 hours

Recommended Number of Students
20, based on BC Technology Educators’ Best Practice Guide

Facilities
Computer lab installed with 3D modelling software (Autodesk Inventor, PTC Creo Parametric, SolidWorks, etc.)
Tools
Projector with computer and speakers, Internet access

Materials
Handout for students with instructions

Resources
Instructional video for teacher and students to follow (Inventor 2013):
  • 12.1: Drawing Side 1 of the Die
  • 12.2: Adding a Sketch to a Surface of a Part
  • 12.3: Assembling Your Die

Teacher-led Activity
Use a computer with a projector and demonstrate the following:
1. Start a new part in imperial.
2. Create the sides of the die in the 2D sketch environment. There are many ways to create the three different sketches needed to complete the die. The suggestion is to start with a 2” square, then offset and draw the lines for the tabs on one side. Next, mirror, copy, and rotate them to the three other sides. Once on all four sides, use the Trim command to remove the unwanted lines.
3. Extrude a 2D sketch into 3D in the part modelling environment.
4. Save the first created part as another file. A suggestion is to have the students create the first drawing and call it side 1, then “Save As” so that they do not have to restart from scratch to complete the other five sides required.
5. Create a second sketch and extrusion on a sketch that has already been extruded.
6. Assemble the sketches together

Student Activity
Students will follow the Student Activity “Make a 3D Die” and/or the video tutorials to make their own 3D die.
**Extension Activity**

Use the drawing below (Figure 1) for outputting to the laser engraver. Insert this drawing into the Student Activity that follows. Have the students change the tabs from .5" to .52" to allow for the “kerf” of the laser. The kerf is based on ⅛" MDF or ⅛" Baltic birch and may vary depending on the laser engraver you have.

**Note:** The male tab will be .02 larger, so that when the die is laser cut it will fit snugly without any glue.

![Figure 29](image)

**Assessment**

Students will show the teacher their completed assignment. The teacher can have the assignment printed out or look at it on the computer screen. If the student does not produce exactly what was shown, then an associated mark based on mistakes can be derived.
Student Activity: Make a 3D Die

Using the software, you are to draw a single die that you will assemble on the screen. The dimensions of the die will be 2” cubed. The die will consist of six separate pieces. However, the top/bottom (1 and 6), two sides (3 and 4), and two ends (2 and 5) will each be the same size (Figure 2).

Figure 3 shows the dimensions of the three pieces you will need to create. The thickness of the material will be ¼”. After the three pieces have been created, you will save a copy of each and then change the number of dots to represent the missing sides of the die.
Procedure for Creating the Sides of Your Die

1. Open a new imperial part from the Application menu or from the Get Started tab on the ribbon (Figure 4).

2. Create a 2D sketch and highlight ANY plane. The program will now enter into the sketch environment (Figure 5).
3. In the sketch environment, create a 2" by 2" square using the Rectangle command (Figure 6).

![Figure 34](image)

4. Offset or draw a line that is .125" in from one of the edges. Draw the start of a tab by drawing 2 lines that are .25" either way from the centre line as shown in Figure 7.

![Figure 35](image)
5. Trim out the excess lines that are not needed to form the “female” part where a tab will join later (Figure 8).

![Figure 36]

6. Add a mirror line on the y-axis so you will be able to mirror the female tab to the other side (Figures 9 and 10).

![Figure 37]
7. Using the Mirror command, select the parts you want to mirror and then select the mirror line. The end result will be that the tab ends up on the other side. Trim out the excess to make it look like Figure 10.

8. Using the knowledge from step 7, create the “male” tab at the top as shown in Figure 11.
9. Mirror and trim out the bottom tab to complete the sketch as shown (Figure 12). Then exit sketch mode.

![Figure 40](image)

10. Extrude the sketch to .125". The end result will be a part looking like the one shown in Figure 13.

![Figure 41](image)
11. Add the holes or indents for the dots. To do this, select “Create 2D Sketch” and then select the surface you want. You will enter into sketch mode again. Each dot on the die will be .4” in diameter. They will ALL be .4” from the outside edges or in the centre of the die as shown in Figure 14.

![Figure 42](image)

12. Once the dot(s) is/are complete for the side of the die you’re working on, finish the sketch (Figure 15). Save your work as *Side 1 – Die*.

![Figure 43](image)

13. You have completed one of the sides of the die. Now you must complete the other five sides using what you have learned above. To create the other sides of the die, you can either start a new drawing and copy and paste the sketch from one drawing to another, OR “Save As” the first drawing to start the next side of the die.
Procedure for Assembling Your Die

1. On the Application menu, select “Create New File,” and this time choose “Assembly.”

![Figure 44]

2. If you have done everything above correctly, you should have a directory containing the six files listed in Figure 17. When you select a file, the Preview window should show a part that corresponds to the file name you’ve selected (Figure 17).

![Figure 45]
3. Place the first part on the screen (Figure 18). This part can be called the grounded part. It is the part that every other piece is connected to. All other pieces will be based off it.

![Figure 46](image)

4. Place the second part. On the Ribbon, select “Constrain.” The “Place Constraints” dialog box comes up, as shown in Figure 19.

![Figure 47](image)

Remember which sides are opposite to each other:

- 1 is opposite 6
- 3 is opposite 4
- 2 is opposite 5
5. Select the two faces of the pieces as shown so that they are aligned flush, as shown in Figure 20. You may have to switch from “Mate” to “Flush” under the “Solution” in the dialog box to get the faces oriented the right way. Select “Apply” when they are lined up correctly.

![Figure 48](image)

6. Select the next two faces of the pieces as shown in Figure 21 so that they are aligned flush. You may have to switch from “Mate” to “Flush” under the “Solution” in the dialog box to get the faces oriented the right way. Select “Apply” when they are lined up correctly.

![Figure 49](image)
7. To ensure the two parts are aligned “Centred,” this time you are going to align them to their planes. In the Browser, expand the parts to show their planes under “Origin.” Picking the planes will highlight them (Figure 22).

8. Once both planes are picked, they will align so that they are mated. Select “Apply” (Figure 23).
9. Continue the process of constraining each part (Figure 24).

10. Once you have placed all the parts and constrained them, you should end up with the completed die as shown in Figure 25. Save your work.
3D Model to 3D Printer/CNC Software

Description
This activity will go through the steps to get from 3D software (Autodesk Inventor) to 3D printer software or CNC software. The challenge sometimes is to ensure the part is designed so that it can actually be printed using a 3D printer or cut on a CNC machine. Once a 3D part has been fully designed in modelling software, it can be exported out.

Lesson Objectives
The student will be able to:

• Understand file formats that different programs/machines use
• Understand how to export the correct format for 3D printers (STL format)

Assumptions
The student will:

• Know how to login to a computer and open up the software
• Have learned how to create parts and assemblies prior to this activity
• Be comfortable using the software

Terminology
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Application button: the icon in the top left corner of the screen that contains New, Open, Save, etc.

Assembly constraints*: rules that determine how parts in an assembly are placed relative to other parts in the assembly. Constraints remove degrees of freedom. Assembly constraints include angle, flush, mate, and tangent. Constraints may be placed between faces of features, part edges, points, inferred axes, and part work features such as planes, axes, and points.

Assembly modelling*: two or more components (parts or subassemblies) considered as a single model. An assembly typically includes multiple components positioned absolutely and relatively (as required) with constraints that define both size and position. Assembly components may include features defined in place in the assembly. Mass and material properties may be inherited from individual part files.
**Browser**: sometimes called the *model tree*, is the graphical hierarchy showing relationships between geometric elements in parts, assemblies, and drawings. Icons represent sketches, features, constraints, or attributes for each model. Objects are shown in the browser in the order in which they were created. Objects may also be edited, renamed, added, deleted, copied, and moved to a different location in the browser.

**Drawing**: a 2D representation of a part or assembly. The drawing file type has an .idw extension.

**Geometry**: lines, circles, etc.

**Graphics window**: the active modelling area in which sketches, constraints, features, parts, and assemblies are created and edited. In the Graphics window, models can be rotated, zoomed in and out, and view characteristics such as colour, material, and light defined.

**Home view**: an isometric view of your model. When the Home button on the ViewCube is pressed, it zooms in and re-orient the model in the isometric view in the Graphics window.

**Navigation bar**: a toolbar containing various tools to move or view your 2D sketch or 3D part in the Graphics window.

**Origin**: the point where the x, y, and z planes or axes intersect.

**Part**: a group of features and faces that have been combined to create a closed volume that is represented as a 3D object.

**Part modelling environment**: the environment where you create sketches and by using different commands eventually create a 3D part. In part modelling, you create sketches, use feature commands to create three-dimensional features, and then combine the features to create parts.

**Ribbon**: the palette that extends across the top of the Inventor interface and contains multiple tabs for convenient tool access.

**Sketch**: consists of the sketch plane, a coordinate system, 2D curves, and the dimensions and constraints applied to the curves. A sketch may also incorporate construction geometry or reference geometry. Sketches are used to define feature profiles and paths.

**Sketch environment**: consists of a sketch and sketch commands. The commands control the sketch grid and draw lines, splines, circles, ellipses, arcs, rectangles, polygons, or points.

**Sketch plane**: a planar face or work plane on which the current sketch is created.

**Estimated Time**
15–30 minutes

**Recommended Number of Students**
20, based on *BC Technology Educators’ Best Practice Guide*
Facilities
Computer lab installed with 3D modelling software (Autodesk Inventor, PTC Creo Parametric, SolidWorks, etc.)

Tools
Projector with computer and speakers, Internet access

Materials
Handout for students with instructions

Resources
Instructional video for teacher and students to follow (Inventor 2013):
• Exporting Your Final Part or Assembly to 3D Printer Software

Teacher-led Activity
Use a computer with a projector to demo/cover the following:
• How to export a file from Inventor to 3D printer software
• How to create a drawing file and modify it (size, layer)
• How to bring parts into a drawing file

Student Activity
No activity. Students can simply watch the video on how to export to a 3D printer.
3D Model to Laser Engraver Software

Description
This activity demonstrates how you can get from 3D software (Autodesk Inventor) to laser engraver software. Schools are going high tech and students are getting access to these machines. A new way of fabricating is starting to happen, where parts for projects are designed on the computer and then cut out on a laser engraver.

Lesson Objectives
The student will be able to:

• Understand how to create an Inventor drawing file from a part or an assembly
• Understand how to modify an Inventor drawing to use with a laser engraver

Assumptions
The student will:

• Know how to login to a computer and open up the software
• Have learned how to create parts and assemblies prior to this activity
• Be comfortable using the software

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Application button: the icon in the top left corner of the screen that contains New, Open, Save, etc.

Assembly modelling*: two or more components (parts or subassemblies) considered as a single model. An assembly typically includes multiple components positioned absolutely and relatively (as required) with constraints that define both size and position. Assembly components may include features defined in place in the assembly. Mass and material properties may be inherited from individual part files.

Browser*: sometimes called the model tree, is the graphical hierarchy showing relationships between geometric elements in parts, assemblies, and drawings. Icons represent sketches, features, constraints, or attributes for each model. Objects are shown in the browser in the order in which they were created. Objects may also be edited, renamed, added, deleted, copied, and moved to a different location in the browser.

Drawing: a 2D representation of a part or assembly. The drawing file type has an .idw extension.
Graphics window*: the active modelling area in which sketches, constraints, features, parts, and assemblies are created and edited. In the Graphics window, models can be rotated, zoomed in and out, and view characteristics such as colour, material, and light defined.

Home view: an isometric view of your model. When the Home button on the ViewCube is pressed, it zooms in and re-orientates the model in the isometric view in the Graphics window.

Navigation bar: a toolbar containing various tools to move or view your 2D sketch or 3D part in the Graphics window.

Origin: the point where the x, y, and z planes or axes intersect.

Part: a group of features and faces that have been combined to create a closed volume that is represented as a 3D object.

Part modelling environment*: the environment where you create sketches and by using different commands eventually create a 3D part. In part modelling, you create sketches, use feature commands to create three-dimensional features, and then combine the features to create parts.

Ribbon: the palette that extends across the top of the Inventor interface and contains multiple tabs for convenient tool access.

Sketch*: consists of the sketch plane, a coordinate system, 2D curves, and the dimensions and constraints applied to the curves. A sketch may also incorporate construction geometry or reference geometry. Sketches are used to define feature profiles and paths.

Sketch environment*: consists of a sketch and sketch commands. The commands control the sketch grid and draw lines, splines, circles, ellipses, arcs, rectangles, polygons, or points.

Sketch plane: a planar face or work plane on which the current sketch is created.

Estimated Time
15–30 minutes

Recommended Number of Students
20, based on BC Technology Educators’ Best Practice Guide

Facilities
Computer lab installed with 3D modelling software (Autodesk Inventor, PTC Creo Parametric, SolidWorks, etc.)

Tools
Projector with computer and speakers, Internet access

Materials
Handout for students with instructions
Resources
Instructional video for teacher and students to follow (Inventor 2013):
  • Exporting Parts to Be Cut on a Laser Engraver MCAD

Teacher-led Activity
Use a computer with a projector to demo/cover the following:
  • How to export a file from Inventor to 3D printer software
  • How to create a drawing file and modify it (size, layer)
  • How to bring parts into a drawing file

Student Activity
Students will follow the video tutorial.