Designer's Toolkit

3D PRINTING CURRICULUM RESOURCES

Contents

Introduction

While 3D printers are growing more popular in high schools around the world, they are not always used to their full educational potential. For busy teachers, there's too little time to develop and test brand new projects and lesson plans. For non-technical instructors, the technology is intriguing – and even tempting—but maybe still too mysterious. So, for many students, while 3D printing is becoming central to the careers and industries they'll soon enter, it's still tough to get hands-on access to the technology.

3D printing isn't just fun, it's a great way to boost student engagement by making abstract concepts tangible and real. If you teach design, engineering, art, math, science, or any other discipline that values critical thinking and creativity, 3D printing can add a completely new dimension to your instruction.

This toolkit and our growing list of project plans can help you incorporate 3D printing into your classroom. Project plans come from some of our top users in education, and they've already been used in the classroom with incredible success. Once you select the projects that best fit your learning objectives, share your experience with us. We'd love to hear from you.

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What is Design?

Design is the thought process comprising the creation of an entity. Its purpose is:

- To meet a need.
- To improve the quality of life.

Some design professions include:

- Architectural design
- Graphic design
- Product design
- Industrial design
- Transportation design
- Engineering design
- Landscape design
- Urban planning
- Game design
- Character design

Design is About People

> *"Design is the process for making things right, for shaping what people need."*
>
> *—Ralph Caplan*

> *"We feel that good design must primarily serve people, and not the other way around."*
>
> *—Thomas J. Watson, IBM*

Critical Thinking in Design

As designers, students will need to make countless analyses and judgments as they work through their projects. In general, thinking will fall into these categories.

Marketing	Evaluating the company, competitors, marketplace, customers and price.
Human factors	Considering how people will behave physically and psychologically in relation to design.
Manufacturing	Determining whether the product will be mass produced, and which materials and manufacturing process should be used.
Form giving	Making aesthetic judgments about proportion of parts, color, use of space and even the object's meaning.

The Design Process

There are many ways to define and map the design process. Whatever process model is used, the stages generally fall into these categories:

Inspiration	Identify a problem or opportunity.
Research	Analyze the problem or opportunity, and gain an understanding of the requirements and constraints.
Concept	Generate ideas that may solve the problem. Choose the best one to develop further.
Development	Search for and define formal characteristics specific to the product including size, scale, measurements and materials.
Formalization	Create working drawings, models and prototypes. Improve and refine these through multiple iterations.

Inspiration

Project modules offered by Stratasys® will serve as the inspiration for student design projects. Each project follows these stages in the design process, and includes a recommended assessment rubric. Projects and assessment criteria can be tailored to your classroom objectives. If you alter a project significantly, we'd love to hear about it and share your experience with other educators.

Research

Students analyze the problem or opportunity, and gain an understanding of constraints. Each project should include research in these four areas, as applicable:

Product History

Studying the evolution of similar products can help students identify trends for new development. Students will better understand the designers who proceeded them, and maybe even find some forgotten or neglected ideas to explore.

Marketplace

Market considerations are fundamental to the success of any new product design. Understanding target consumers and what motivates them to buy is the basis for all successful business.

Manufacturing

Often introducing a new material, process or assembly procedure can mean the difference between success and failure. Students should be able to answer the following questions:

1. What materials make up this product?
2. How are the parts and components made?
3. How are they assembled?
4. Why are these practices used today?
5. Why are other materials, processes and assembly sequences not used?

Concept

Students will explore design options using each of the following methods. See Design Drawing Standards for more information.

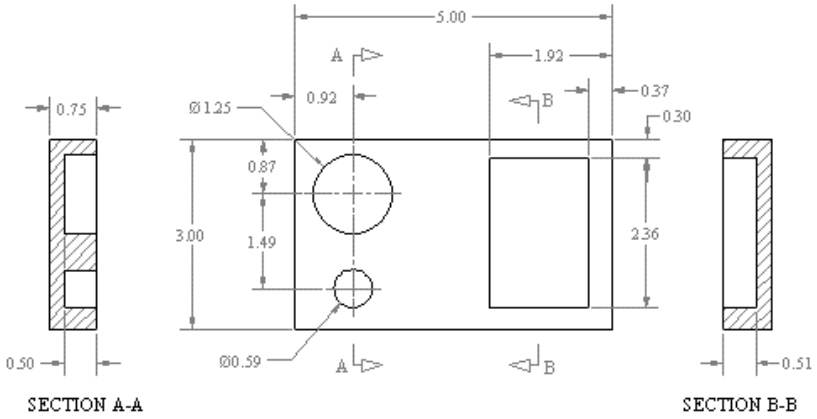
Concept Sketches

1. Using pencil or marker, draw a minimum of 10 to 15 ideas. These should be freehand, and not to scale.
2. Color the sketch you've chosen for your final design. Try to color the sketch to represent the final materials (E.g. plastic, metal).
3. Include any notes about functions or features not evident from the sketch.

Scaled Sketches

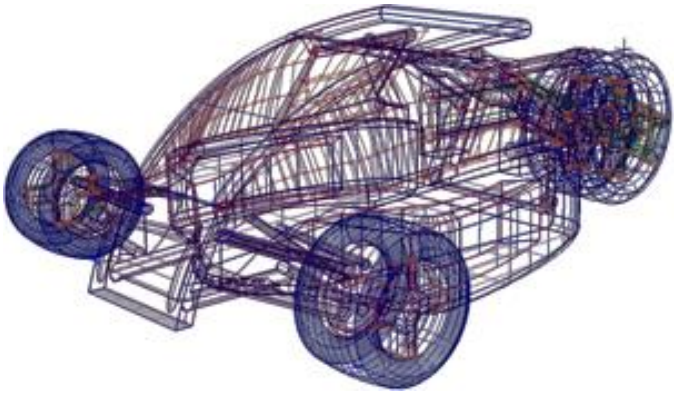
1. All scaled sketches are to be completed on graph paper to a scale determined by the product being designed.
2. In pencil only, produce the views necessary to describe the product completely. Use a scale, set square, circle and ellipse templates, french curve and compass to produce an accurate and neat set of scaled sketches.
3. Include all dimensions.

Development



Students will finalize the size and shape of their project.

Formalization



Students will produce 3D sketches using CAD software.

Students will produce render images using CAD software.

Design Drawing Standards

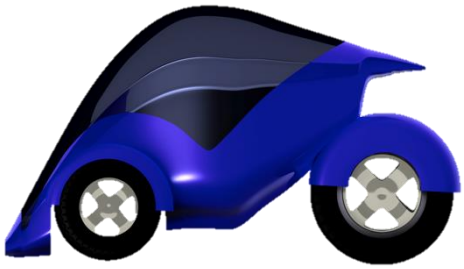
Orthographic Projection

Orthographic projection is a means of representing 3D objects in a two-dimensional medium, like a drawing or a print. It provides multiple views of an object from viewpoints rotated about the object's center, usually by increments of 90 degrees.

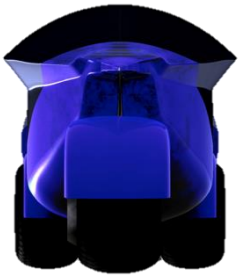
Orthographic views describe an object's surface geometry completely.

Orthographic views of a concept car

Front view



Side view



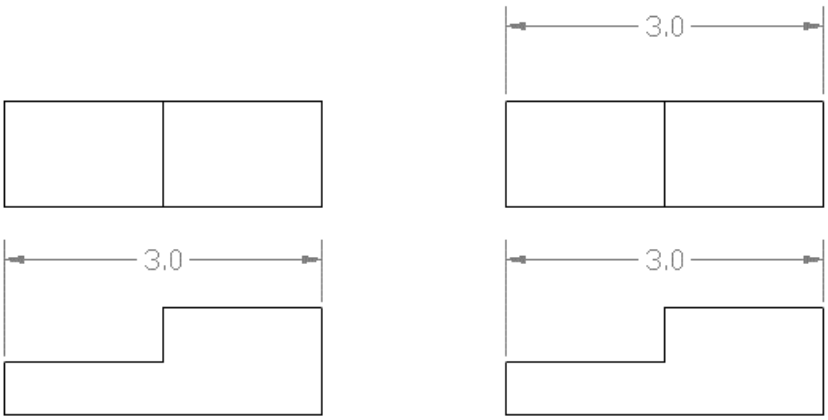
Back view

Working Drawings

A working drawing is one from which a tradesperson can manufacture a part. The drawing must be a complete set of instructions so that the manufacturer requires no additional information. A working drawing contains all necessary views, dimensions and specifications, such as material, weight or color. Required specifications can be noted on the drawing or in the title block.

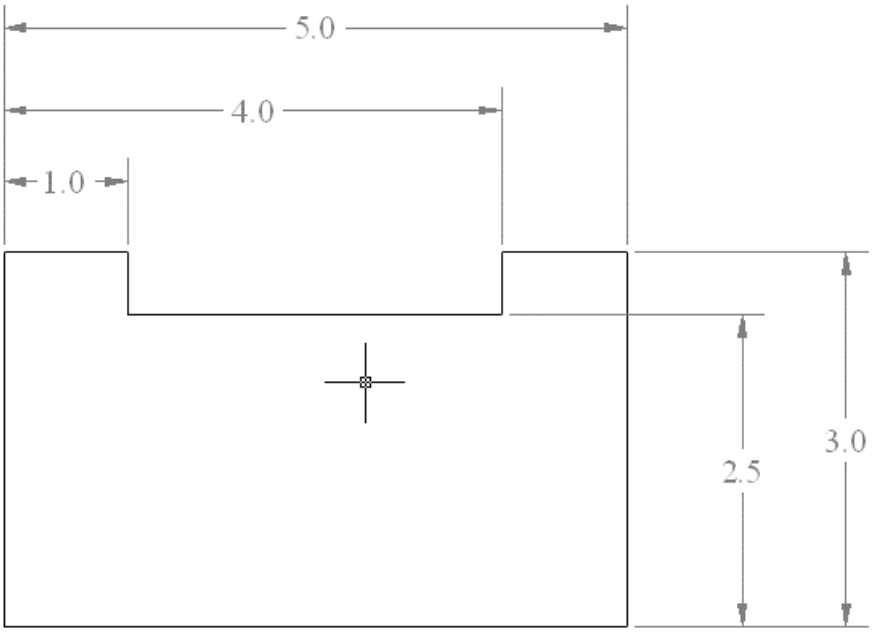
Dimensioning Rules and Best Practices

Do not repeat dimensions on multi-view drawings.



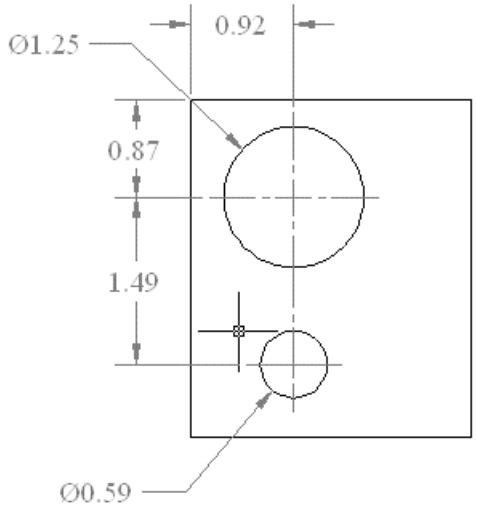
Correct *Incorrect*

Place overall dimensions outside the smaller dimensions.



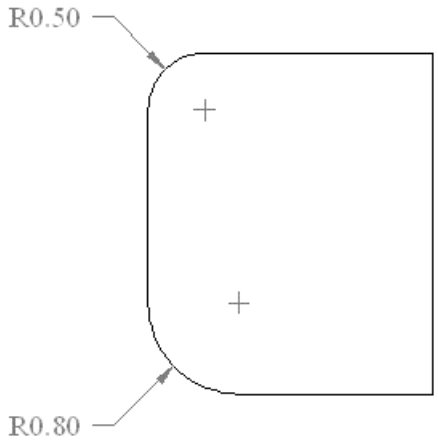
Provide dimensions from centerlines when necessary.

Always provide a hole's diameter, not its radius.

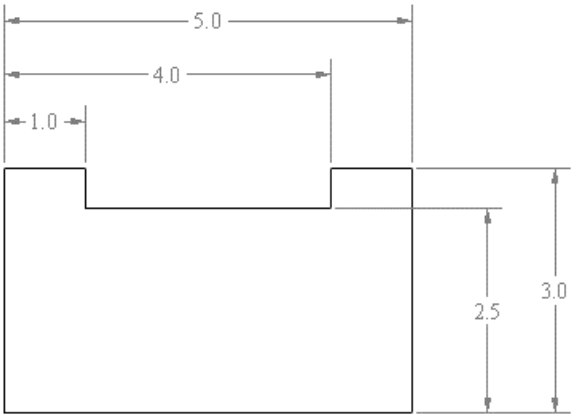


Always provide an arc's radius using a leader.

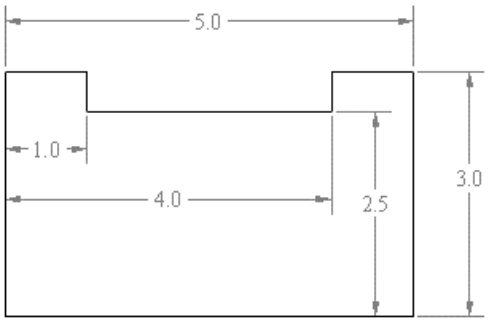
An "R" should be placed before the value.



Do not place dimensions inside the view outlines.

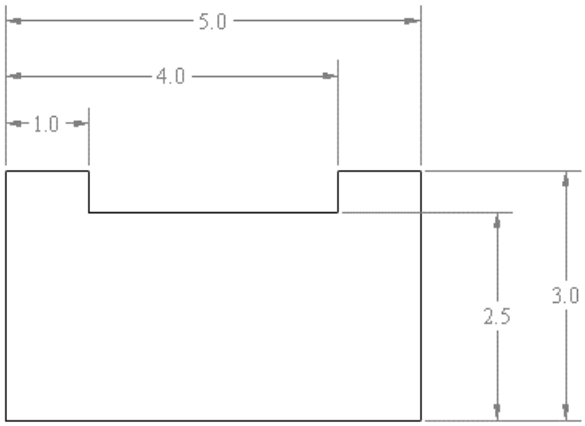


Correct



Incorrect

Place extension lines where they do not cross dimension lines.



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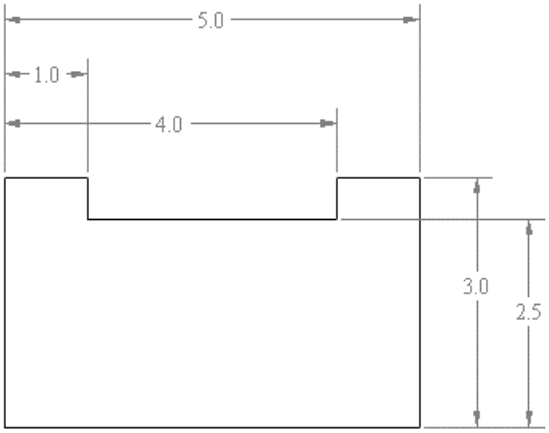
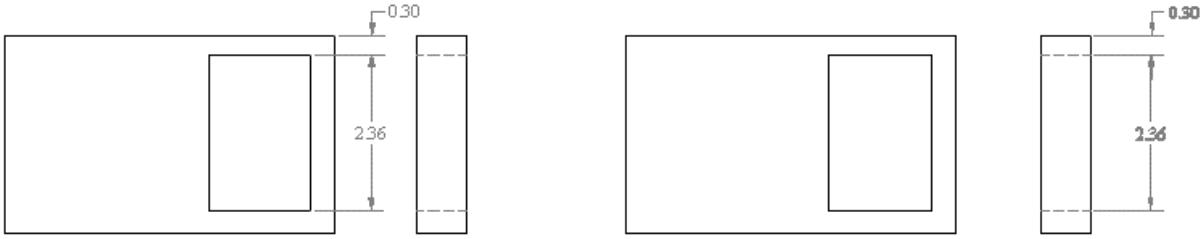


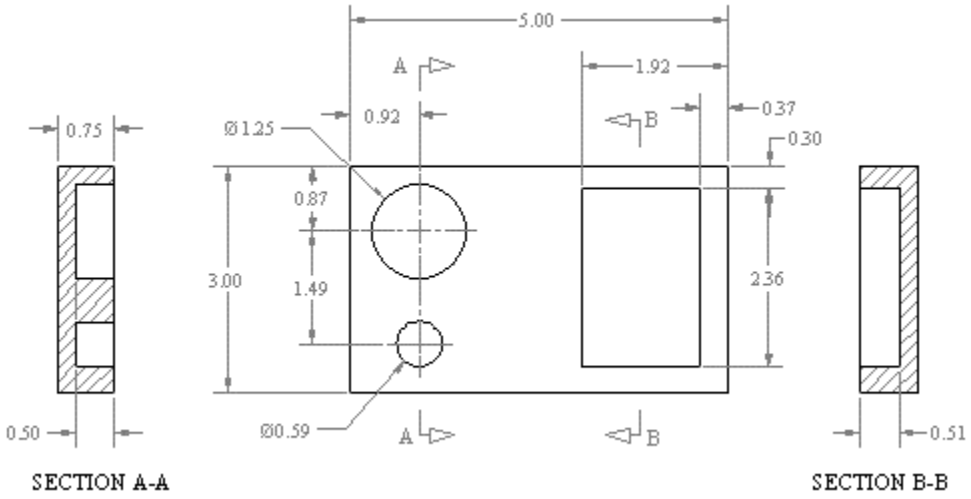
Incorrect

Avoid dimensioning to hidden lines.



Correct Incorrect

Place dimensions near the views, between the views and above the views if possible.



Choosing the Right Project

Student Proficiency

Each project module is designed for a specific student proficiency level. We recommend assessing student proficiency using the following criteria, and choosing corresponding projects for classroom use. The goal of each project module is to increase student proficiency from one level to the next.

Beginner

Choose beginner projects for students who have had little or no previous experience with CAD or technical drawings. After completing a beginner project, students should demonstrate knowledge, understanding and application of the following:

- The design process, as described in this toolkit
- Orthographic projection, including the ability to create a three-view technical drawing
- Working knowledge of one 2D CAD program
- Introductory understanding and knowledge of one 3D CAD program
- Ability to create an STL file for 3D printing

Intermediate

Choose intermediate projects for students who have previous experience with CAD and 3D design. In addition to the above proficiencies, after completing an intermediate-level project, students should demonstrate knowledge, understanding and application of the following:

- The use of Catalyst software to execute a 3D print
- Moderately complex design concepts that reflect greater breadth and scope
- Mastery of at least one 3D CAD software program

Advanced

Choose advanced projects for experienced, self-directed design students, especially independent learners with an eye for design. In addition to *intermediate* proficiencies, the advanced student should demonstrate knowledge, understanding and application of the following:

- The use of Catalyst software to scale, copy, and to change orientation to execute a 3D print
- Highly complex design concepts that reflect greater breadth and scope
- Mastery of two or more CAD programs

Resources

CAD Resources

123D. http://www.123dapp.com/howto/design

AutoCAD Inventor. http://knowledge.autodesk.com/support/inventor-products/getting-started

GrabCad. https://grabcad.com/questions

Pro/Engineer Wildfire. http://www.ptc.com/community/landing/wf3.htm

PTC Creo. http://www.ptc.com/product/creo/interactive-experience

Sketchup. http://www.sketchup.com/learn

SolidWorks. https://www.solidworks.com/sw/resources/solidworks-tutorials.htm

Thingiverse. http://www.thingiverse.com/

TinkerCAD. https://www.tinkercad.com/about/learn

Textbooks

Madsen, David A., and David P. Madsen. 2012. *Engineering Drawing and Design 5th edition*. Delmar Cengage Learning.

Ulrich, Karl T., and Steven D. Eppinger. 2012. *Product Design and Development, 5th edition.* Irwin McGraw-Hill.

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Flinchum, Russell. 1997. *Henry Dreyfuss, Industrial Designer: The Man in the Brown Suit.* Rizzoli International.

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Olofsson, Erik, and Klara Sjölén. 2007. *Design Sketching.* KEEOS Design Books.

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Powell, Dick. 1990. *Presentation Techniques: A Guide to Drawing and Presenting Design Ideas.* Little, Brown & Company.

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Cadalyst. http://www.cadalyst.com.

Car Body Design. http://www.carbodydesign.com.

Card Design News. http://www.cardesignnews.com.

Core77. http://core77.com.

Designboom. http://www.designboom.com.

Dezeen. http://www.dezeen.com.

Dwell. http://www.dwell.com.

Industrial Designers Society of America. http://www.idsa.org.

Project Lead the Way. https://www.pltw.org.

Magazines

Auto and Design. Italy.

Azure. Canada.

Newdesign. United Kingdom.

Acknowledgements

Stratasys would like to express our deep appreciation to **Mike Santalupo**, design teacher at John Paul II Catholic Secondary School in London, Ontario, for his valuable and constructive contributions to this toolkit and related project modules. His expertise, experience and eagerness to promote 3D printing in the classroom have been essential to developing this resource for teachers everywhere.

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