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# INTRODUCTION TO COMPUTER AIDED MANUFACTURING

EDUC-4009

PRESENTED TO

Ken Hartikainen and
Justin Pasosky

PRESENTED BY

Daniel Strang

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# COURSE AIM

Students will become literate in computer aided design and confidently apply their skills to computer-aided manufacturing processes, elevating their proficiency in both areas.

# COURSE DESCRIPTION

You wouldn't download a car, but what if you could? We aren't able to print entire cars quite yet, but 3D printing and other Computer Aided Manufacturing technologies are rapidly developing. This 100 hour course will explore the use of Computer Aided Design through hands-on project based learning. Students will be encouraged to use their creativity and problem-solving skills.

## COURSE DURATION - 100 HOURS

## COURSE PREREQUISITES

This course has no prerequisites

# RATIONALE

Computer Aided Manufacturing (CAM) has become common in industrial arts classes. Most industrial arts classrooms are equipped with computer numerical control (CNC) equipment including 3D printers, laser cutters, CNC routers and CNC plasma cutters. These technologies are important parts of modern industrial arts classrooms and this course will take students' projects to another level by focusing on developing their literacy in Computer Aided Design (CAD) and CAM skills. These skills will follow students throughout the rest of their time in industrial arts programs.

Students will be able to apply the CAM skills they begin to develop in this course to a wide range of careers. 3D printing, for example, has become common for rapid prototyping of products as well as small scale or artisan manufacturing applications including jewelry and dentistry. There are also many emerging 3D printing technologies, including concrete 3D printing of foundations and entire buildings, and manufacturing of “practice organs” for surgeons to improve surgery success rates.

In addition to skills directly related to CAM, this course will also build students’ general digital literacy. Students will be presented with several softwares to learn, developing their ability to learn new software in their future careers. Working with CAD software improves students’ spatial abilities and provides experience applicable to careers including architecture, engineering, animation and game design.

# THE LEARNER

This course is designed for Grade 9 Students. Most students will enter this course with little to no CAM experience. Some students may have used CAD and CAM on a very basic level in grade 8 Industrial Arts classes, but would still be essentially starting from square one. For a while elementary schools were putting 3D printers in classrooms, but the vast majority of teachers had no idea what to do with them. Most students have some digital literacy skills from social media and use of software like word and powerpoint in school. If students' digital literacy is lacking, they can still be successful in the course, but will require more work by the student and teacher during the first unit where students learn CAD.

# COURSE GOALS

1. Discuss the basic principles and techniques of computer-aided manufacturing (CAM) and its applications in various industries
2. Apply safe practices and procedures when operating CAM equipment
3. Develop the ability to use computer-aided design (CAD) software to create and edit 2D and 3D models for manufacturing processes
4. Explore the different types of CNC machines and their capabilities, as well as how to properly program and operate them
5. Develop the ability to analyze and solve problems related to CAM processes and equipment
6. Develop skills transferable to other areas of industrial arts where they can be used to elevate projects in those classes
7. Explore emerging CAM technologies and their potential impacts on industry
8. Inspire creativity by using CAM techniques to design and produce innovative products

# TOPICAL OUTLINE

The course is divided into five units. The first unit introduces students to the course and the main computer aided design software they will be using throughout. Unit 2 introduces students to 3D printing with a design challenge. Third is the flat-pack furniture project where students are introduced to the laser cutter and CNC router. The last manufacturing unit is a sign manufactured with the CNC plasma cutter. Finally, the course will end with a research project.

| | |
|---|---|
| **Unit 1** | Computer Aided Design (13 hours) |
| **Unit 2** | Functional Object Design Challenge (25 hours) |
| **Unit 3** | Flat-pack Furniture Project (30 hours) |
| **Unit 4** | CNC Plasma Sign (17 Hours) |
| **Unit 5** | Research Project (15 Hours) |

# UNIT 1: COMPUTER AIDED DESIGN

## Unit Description

In this unit, students will become familiar with the computer aided design software they will be using throughout the course. The first task will be getting students acquainted with the computer setup in the classroom. They will need to log onto the computers and learn where to hand in assignments, access resources and open programs. Some software also requires students to make individual accounts which can be a lengthy process.

The specific software used in this course should change over time to stay consistent with what industry is using. Right now, this course would be taught with Siemens Solid Edge as the 2D CAD software and Autodesk Fusion 360 as the 3D CAD software.

Once students are able to access the software, the class will go through a series of lessons on basic operations. These lessons will start with a demonstration from the teacher, followed by individually working on tutorials prepared by the teacher. These tutorials will produce simple designs that can then be assessed by the teacher.

# UNIT 1: COMPUTER AIDED DESIGN

## Learning Outcomes

| LEARNING OUTCOME<br>THE LEARNER WILL BE ABLE TO: | K<br>S<br>A | INSTRUCTIONAL STRATEGIES | MATERIALS & EQUIPMENT |
|---|---|---|---|
| GLO 1 - Develop skills in computer aided design to create, modify, and communicate design information | S | Lectures, Self-directed tutorials, one-on-one help | Computers with CAD software |
| SLO 1.1 - Create and modify basic 2D and 3D designs using CAD tools | S | Lectures, Self-directed tutorials, one-on-one help | Computers with CAD software |
| SLO 1.2 - Communicate designs using clear annotations and drafting standards | S | Lectures, Self-directed tutorials, one-on-one help | Computers with CAD software |
| SLO 1.3 - Manage CAD files by importing, exporting, converting, and organizing data in a variety of file formats | S | Lectures, Self-directed tutorials, one-on-one help | Computers with CAD software |

# UNIT 1: COMPUTER AIDED DESIGN

## Topical Outline

| TOPIC | SUBTOPICS | ASSESSMENT | TIME |
|---|---|---|---|
| Navigating the software | Making Accounts | CAD Tutorials | 2 hours |
| 2D CAD | Proper use of Layers<br>2D drawing<br>Transforming 2D drawings | CAD Tutorials | 5 hours |
| 3D CAD | Creating 3D models<br>Transforming and modifying 3D models<br>Transforming 2D designs into 3D | CAD Tutorials | 5 hours |
| Annotations and Organization | Accurate Labelling, marking, and dimensioning<br>Organizing and naming components and bodies<br>Effective file naming and organization | CAD Tutorials | 1 hour |
| | | **Total Time:** | **13 hours** |

# UNIT 2: **FUNCTIONAL OBJECT DESIGN CHALLENGE**

## Unit Description

This unit introduces students to 3D printing. It begins with some additional computer aided design theory covering design considerations for creating physical objects, including measurement and scale. This section will also cover what must be included in designs to be able to actually 3D print them.

The next section will cover the different types of 3D printers and the various materials that these printers are able to use. Students will examine what circumstances each material and 3D printer type are most appropriate.

The major project for this section is the functional object design challenge. Students will be given a design brief that instructs them to design and 3D print an object that has some function other than being nice to look at. This can be structured in a few different ways depending on the students. Some groups of students may easily come up with objects they want to print to solve a problem in their own lives. Other classes might struggle with that much freedom, so project could be centered around a theme where every student designs, for example, a desk organizer of some sort.

# UNIT 2: FUNCTIONAL OBJECT DESIGN CHALLENGE

## Learning Outcomes

| LEARNING OUTCOME<br>THE LEARNER WILL BE ABLE TO: | K<br>S<br>A | INSTRUCTIONAL STRATEGIES | MATERIALS & EQUIPMENT |
|---|---|---|---|
| GLO 2 - Design and 3D print a functional object | K<br>S<br>A | Lectures, project | Computers with CAD software and Slicer software. 3D printers |
| SLO 2.1 - Design a real-world object | S | Project | Computers with CAD software |
| SLO 2.2 - Utilize slicer software to effectively generate toolpaths for 3D printing, ensuring optimal results | S | Self-directed tutorial, one-on-one help | Computers with Slicer software |
| SLO 2.3 - Evaluate the applications of different 3D printing materials and their unique properties | K | Lecture | Sample 3D prints |
| SLO 2.4 - Determine the most appropriate 3D printing technology for the project | K | Lecture | 3D Printer |

# UNIT 2: **FUNCTIONAL OBJECT DESIGN CHALLENGE**

## Topical Outline

| TOPIC | SUBTOPICS | ASSESSMENT | TIME |
|---|---|---|---|
| 3D Modelling for the real world | Ensuring models are complete and "watertight" for 3D printing<br>Measurement | | 2 hours |
| Types of 3D printers | Available materials<br>Variations within types of printers | | 1 hour |
| Slicer software | What makes a successful print<br>Important settings and considerations | | 2 hours |
| Design and 3D print a functional object | | Functional object project | 20 hours |
| | | **Total Time:** | **25 hours** |

# UNIT 3: **FLAT-PACK FURNITURE PROJECT**

## Unit Description

In this unit, students will design and produce a piece of flat-pack furniture. This is a piece of furniture made entirely out of one sheet of plywood and, in theory, able to be disassembled and shipped in a smaller container than a fully assembled piece.

The unit begins with lessons on furniture design, covering ergonomics and aesthetics, as well as joinery and structural integrity.

This project employs the laser cutter and CNC router, both tools that have some risk associated with them. Students will view safety demos and complete safety tests for both pieces of equipment before they are permitted to operate them.

Students will start by designing a small scale prototype, which they will cut out using the laser cutter. The laser cutter cuts material quickly and small scale prototypes use up minimal material. The prototypes will be assessed by peer feedback, and students will have the opportunity to refine their designs before cutting them out full scale on the CNC router.

# UNIT 3: FLAT-PACK FURNITURE PROJECT

## Learning Outcomes

| LEARNING OUTCOME<br>THE LEARNER WILL BE ABLE TO: | K<br>S<br>A | INSTRUCTIONAL STRATEGIES | MATERIALS & EQUIPMENT |
|---|---|---|---|
| GLO 3 - Design and produce a piece of flat-pack furniture. | K<br>S<br>A | Lecture, one-on-one help | Computers with CAD software |
| SLO 3.1 - Explore the principles of furniture design and ergonomics and how they impact the functionality and aesthetics of the final product | K<br>A | Lecture | Sample furniture |
| SLO 3.2 - Utilize a laser cutter for prototyping and testing furniture designs | S | One-on-one help, peer feedback | Computers with CAD software, laser cutter, plywood |
| SLO 3.3 - Apply safe laser cutter practices, including proper cut settings and material choices | K | Safety Demo | Sample materials |
| SLO 3.4 - Utilize a CNC router to create precise cuts and shapes in a variety of materials | S | Safety Demo | Computers with CAD software, CNC router, plywood, wood glue |
| SLO 3.5 - Implement sustainable manufacturing practices including efficient nesting techniques and use of renewable materials | K<br>A | Lecture | Sample materials |

# UNIT 3: **FLAT-PACK FURNITURE PROJECT**

## Topical Outline

| TOPIC | SUBTOPICS | ASSESSMENT | TIME |
|---|---|---|---|
| Furniture Design | Ergonomics and Aesthetics<br>CNC Joinery | | 9 hours |
| Laser Cutter | Safety<br>Determining settings | Safety test<br><br>Furniture prototype | 10 hours |
| Sustainable Practices | Efficient nesting techniques | | 1 hour |
| CNC Router | Safety<br>Determining feeds and speeds<br>Bit types | Safety test<br><br>Flat-pack furniture | 15 hours |
| | | **Total Time:** | **30 hours** |

# UNIT 4: **CNC PLASMA SIGN**

## Unit Description

This unit introduces students to the CNC plasma cutter. As with the previous units, this unit begins with theory lessons about how plasma cutters work and the design considerations students will need to follow for a successful project.

The plasma cutter requires the completion of a safety demo and safety test before students will be permitted to operate the machine.

The default project for this unit is a metal nameplate. Students will cut out their name along with some decorative artwork. Students can be given the opportunity to design a more complicated project, for example metal wall art or a fire pit.

# UNIT 4: CNC PLASMA SIGN

## Learning Outcomes

| LEARNING OUTCOME<br>THE LEARNER WILL BE ABLE TO: | K<br>S<br>A | INSTRUCTIONAL STRATEGIES | MATERIALS & EQUIPMENT |
|---|---|---|---|
| GLO 4 - Design and manufacture a product using the CNC plasma cutter | S<br>A | Lecture, one-on-one help | Computers with CAD software, plasma cutter |
| SLO 4.1 - Discuss hazards associated with plasma cutters and apply appropriate safe work procedures | K | Safety demo | Plasma cutter |
| SLO 4.2 - Analyze the properties of available materials and select the most appropriate one for the project | K | Lecture | Sample materials |
| SLO 4.3 - Create designs and toolpaths that are optimized for CNC plasma cutting, taking into account factors like cutting speed, material thickness, and capabilities of the machine. | S<br>A | Lecture, one-on-one help | Computers with CAD software, plasma cutter |

# UNIT 4: **CNC PLASMA SIGN**

## Topical Outline

| TOPIC | SUBTOPICS | ASSESSMENT | TIME |
|---|---|---|---|
| Plasma Cutter Safety | | Safety Test | 2 hours |
| How a plasma cutter works | Material choice<br>Cut speed<br>Electrical power<br>Air pressure | | 3 hours |
| Metal Sign/Wall Art | CNC plasma design considerations | Metal sign / wall art | 12 hours |
| | | **Total Time:** | **17 hours** |

# UNIT 5: **RESEARCH PROJECT**

## Unit Description

The final unit consists of a research project and a final portfolio. Students will conduct research on a new or emerging computer aided manufacturing technology. Students will gain skills and experience determining the viability of new technologies through thorough research and communications with experts.

Students will then practice their communication skills by presenting what they have found through their research. Students can choose to create a presentation to the class, a video presentation, or a poster as the default projects. If students have another way they would like to communicate their research this project is intended to be flexible enough to reasonably accommodate other types of communication.

For the last assignment in the course, students will produce a portfolio showcasing the three manufacturing projects they have completed, along with the research project. This assignment will be accompanied by in-class discussions about working and getting hired in industries using computer aided manufacturing.

# UNIT 5: **RESEARCH PROJECT**

## Learning Outcomes

| **LEARNING OUTCOME**<br>THE LEARNER WILL BE ABLE TO: | **K**<br>**S**<br>**A** | **INSTRUCTIONAL STRATEGIES** | **MATERIALS & EQUIPMENT** |
|---|---|---|---|
| GLO 5 - Critically evaluate the potential of emerging CAM technologies in solving problems | K<br>A | Lecture, independent research | Internet access |
| SLO 5.1 - Analyze the effectiveness and viability of an emerging CAM technology in resolving a problem compared to existing solutions and technologies | K<br>A | Lecture, independent research | Internet access |
| SLO 5.2 - Gather and synthesize information from multiple sources about a selected emerging CAM technology | S<br>A | Lecture, independent research | Internet access |
| SLO 5.3 - Communicate research findings effectively and accurately | S<br>A | Research presentation | Projector, large format printer, video camera |
| SLO 5.4 - Develop a personalized strategy for utilizing the benefits of emerging CAM technologies in a relevant industry or field | K<br>A | Portfolio project | Internet access |

# UNIT 5: **RESEARCH PROJECT**

## Topical Outline

| TOPIC | SUBTOPICS | ASSESSMENT | TIME |
|---|---|---|---|
| Evaluate new CAM technology | Is a new technology just marketing or is it actually a useful innovation<br>Research and verify facts | Research project | 5 hours |
| Communicate research findings | Organization of information<br>Communication | Research project | 5 hours |
| Career development | Positioning oneself to leverage new technology | Portfolio | 5 hours |
| | | **Total Time:** | **15 hours** |

# EVALUATION

| UNIT | ASSIGNMENT | METHOD OF ASSESSMENT | TIME TO MARK CLASS OF 20 | WEIGHT |
|---|---|---|---|---|
| Computer Aided Design | CAD Tutorials | Marked by teacher with rubric | 2 hours | 10% |
| Functional Object | Functional Object | Marked by teacher and student with rubric | 1.5 hours | 20% |
| Flat-pack Furniture | Safety Tests | Marked by teacher with key | 0.5 hours | 5% |
| | Prototype | Peer feedback with rubric | 0.5 hours | 5% |
| | Flat-pack Furniture | Marked by teacher and student with rubric | 1.5 hours | 20% |
| CNC Plasma Sign | Safety Test | Marked by teacher with key | 0.5 hours | 5% |
| | Metal sign/wall art | Marked by teacher and student with rubric | 1.5 hours | 20% |
| Research Project | | Varies by choice of communication style | 2-5 hours | 15% |
| | | **Total:** | **10-13 hours** | **100%** |

# EVALUATION


## CAD Tutorials


## Safety Tests


## Manufacturing Projects


## Research Project

# LOGISTICS

This course relies heavily on four types of somewhat specialized equipment. 3D printers and laser cutters have become relatively common in schools, and 3D printers especially are currently very affordable and easy to implement into a classroom.

A large format CNC router is required for the flat pack furniture project. Some schools have these but they are by no means standard. Ideally this equipment would be acquired through a grant but if that is not possible. A smaller CNC router can be acquired and a different project can be taught using that tool.

CNC plasma cutters are somewhat common in schools that have metalworking labs, but not all schools have those facilities. Similarly to the large format CNC router, this equipment would require grant funding to acquire and install. If that is not possible, another project can be added that combines 3D printing with laser cutting and/or the CNC router

Ideally, this course would have a dedicated classroom with a design lab and all four CAM tools covered in the same area. This is not likely to be the case when this course is first introduced, and there may never be the facilities available in the school. In this case, equipment would be spread across several classrooms, so cooperation between teachers in the Industrial Arts department would be crucial for a successful program. Teachers in the labs containing the equipment would need to be aware of the projects in this course and willing and able to supervise extra students in their labs.