

Design and Fabrication 2202



Government of Newfoundland and Labrador
Department of Education

***Curriculum Guide (interim)
September 2009***

Contents

Acknowledgements	iii
Foreword	v
Introduction	1
Background	1
Overview and Rationale.....	1
Purpose of Curriculum Guide.....	2
Context for Learning	2
Literacy Through Technology Education	4
Meeting the Needs of All Learners	5
Effective Assessment and Evaluation Practices	6
Program Design and Components	7
Program Components	7
Outcomes Structure	8
Essential Graduation Learnings	8
General Curriculum Outcomes.....	9
Key Stage Curriculum Outcomes	9
Specific Curriculum Outcomes	13
Unit 1: Engineering Design and Manufacture	13
Unit 2: CNC Programming Basics	37
Unit 3: Basic CNC Operations	61
Unit 4: Three-Dimensional Computer Aided Design	83
Unit 5: Computer Aided Manufacturing	111
Unit 6: The Design Project	133
Unit 7: Careers in CAD/CAM/CNC	165



Acknowledgments

The Department of Education for Newfoundland and Labrador gratefully acknowledges the contribution of the following individuals and members of the provincial Skilled Trades and Technology Working Group, in the completion of this guide:

Randy Ash
Program Development Officer
Division of Institutional and Industrial Education
Department of Education

John Barron
Program Development Specialist
Division of Program Development
Department of Education

Gonzo Bennett
Teacher
Mount Pearl Senior High School, Mount Pearl

Tony Hillier
Program Development Specialist
Division of Program Development
Department of Education

Rod Lundrigan
Teacher
O'Donel High School, Mount Pearl

Mr. John O'Leary
Instructor
College of the North Atlantic, St. John's

Edward Reddick
Teacher
Holy Heart High School, St. John's

Ron Smith
Program Development Specialist
Eastern School District



Introduction

Background

Design and Fabrication 2202 is based conceptually, philosophically and practically on the Atlantic Canada Foundation document for Technology Education (2001). The teacher is directed to the document for specific information that forms the basis for this and other technology education curricula in the province of Newfoundland and Labrador.

This two-term course reinforces and extends on the basics of engineering design, fabrication processes and shop safety covered in Design and Fabrication 1202. Design and Fabrication 2202 introduces students to some of the more advanced design and manufacturing tools used today including 2D and 3D Computer Aided Drafting and Design (CADD) software, 3D Computer Aided Manufacturing (CAM) software, and Computer Numerical Control (CNC) machining.

Rationale

This course is designed for delivery using a problem-based learning approach which reflects standard industry practice in the fields of engineering design and advanced manufacturing. Using this approach, the teacher takes on the role of facilitator in helping students to acquire the technical knowledge and basic proficiency needed to perform each of the major operations that comprise the CAD/CAM process for part production, including creating the CAD model, generating the CNC part program using CAM software, and setting-up/operating a CNC machine.

Students first learn the basics of CAD/CAM/CNC through completion of a series of introductory lab/shop projects that allow them to actually experience the CAD/CAM process from the initial design concept to the finished CNC produced part. Students then apply the knowledge and skills developed through these activities in the completion of a major Design Project that must incorporate the CAD/CAM process.

This experiential approach encourages students to “learn by doing” and, thereby, develop the problem-solving and teamwork skills fundamental to industry practice in the fields of engineering and manufacturing. The major Design Project allows students to generalize, apply and synthesize the concepts learned over the duration of the course. Students, working in groups of 2, must identify the required project activities, develop a related project timeline, assign and schedule project activities, identify/procure the raw material and equipment needed, and determine a per unit

Rationale cont'd

production cost. Ideally, projects will support a real need in industry and directly involve industry representatives in student learning.

Purpose of Curriculum Guide

The purpose of this curriculum guide is to provide teachers with a clear delineation of student expectations in the course. The guide includes the specific curriculum outcomes, suggested learning and teaching strategies, suggested assessment and evaluation strategies and support resources.

Context for Learning

As stated in the Atlantic Canada Foundation document for Technology Education (2001), the Technology education curriculum in Atlantic Canada adheres to certain principles that guide decisions shaping the continuous improvement of learning and teaching including the design and implementation of the curriculum. These include:

Authenticity

Technology education values and embraces the strategic links between applied learning and integrated learning.

Unity

Technology education values and embraces meaningful connections among diverse areas of study.

Constructivism

Technology education incorporates each individual's prior knowledge, skills, and attitudes in the design of authentic learning experiences.

Collaboration

Technology education curriculum in Atlantic Canada adheres to strategies that emphasize the unifying concepts of related disciplines, particularly science.

Autonomy

Technology education values an environment with the learner as its pivotal force.

Continuous Inquiry

Continuous inquiry is essential to technology education.

Continuous Improvement

The success of technology education initiatives is a function of informed implementation and improvement practices.

Continuous Learning

Technology education implies strategic and distinct pre-service and in-service demands on teacher education.

Context for Learning cont'd

Design and Fabrication 2202 encourages student collaboration in solving technical problems and reflects true industry practice through the use of a problem-based learning approach. Continuous inquiry, improvement and learning are fundamental to this approach and the design project provides an authentic learning experience where students drive the learning.

Literacy through Technology Education

As noted in the Atlantic Canada Foundation document on Technology Education, in order to acquire technological “literacy”, students must be given the opportunity to actively participate in the solution of technical problems. In support of this, it is recommended that delivery of Design and Fabrication 2210 be focused on the shop/lab setting with intermittent classroom instruction only as required. This is consistent with instructional delivery models used in post-secondary technology education programs. Trades apprentices seeking journeyman certification, for example, are required to complete a training program that consists of 20% classroom-based instruction and 80% field experience. This mode of instructional delivery provides students with opportunities to:

- Identify, assess, and make decisions about their use of technological resources
- Assess their technological literacy/capability in the context of specific situations
- Develop personal action plans to acquire specific technical skills and capabilities
- Safely use a wide variety of technological systems, tools, and other resources
- Identify and address technological issues and situations important to them
- Design, develop, and articulate technological solutions to a wide range of problems
- Articulate ideas and take intellectual risks
- Reflect on and evaluate their learning
- Reflect on, evaluate, and express ideas and opinions on the relationship between technology and education and the role of technology education
- Assess technology as a force for change in a variety of workplaces, jobs, occupations, and careers

The Design Project requirement of Design and Fabrication 2202 is particularly important to the goal of technological literacy. It encourages students to become increasingly independent (and interdependent) learners with the teacher taking on the role of facilitator. As facilitator, the teacher’s role will be focused on overall project management, shop safety compliance, monitoring of

Literacy through Technology Education (cont'd)

student group progress, and student evaluation. While student groups will be responsible for management of their own projects, regular monitoring of group activities will be necessary to help identify topics that may require formal instruction by the teacher on an individual, group, or class basis.

Meeting the Needs of All Learners

In the Atlantic Canada Foundation document on Technology Education (2001), it is suggested that in a learning community characterized by mutual trust, acceptance, and respect, student diversity is both recognized and valued. Educators should ensure that classroom practices and resources positively and accurately reflect diverse perspectives and reject prejudicial attitudes and discriminatory behaviours. It is also suggested in the document that if curriculum is to contribute to the achievement of equity and quality in education, it must:

- Reflect students' abilities, needs, interests, and learning styles
- Expect that all students will be successful regardless of gender, racial and ethno-cultural background, socioeconomic status, lifestyle, or ability
- Enable students to value individual variation among members of their classroom community

Design and Fabrication 2202 considers a wide range of learners and learning styles through a problem-based learning approach that encourages experiential learning. This student-centered learning model emphasizes a group approach to problem-solving that requires students to take ownership of their own learning. As suggested in the Atlantic Canada Foundation document on Technology Education (2001), taking ownership and responsibility for their own learning is a significant element in the growth of a student's technological capability.

Effective Assessment and Evaluation Practices

The Atlantic Canada Foundation document on Technology Education (2001), recommends that in planning assessments, teachers should use a broad range of strategies in an appropriate balance to give students multiple opportunities to demonstrate their knowledge, skills, and attitudes. The document identifies many types of assessment strategies as suitable for technology education including:

- Formal and informal observations
- Work samples
- Anecdotal records
- Conferences
- Teacher-made and other tests
- Portfolios
- Learning journals
- Questioning
- Performance assessment
- Peer- and self-assessment

Effective Assessment and Evaluation Practices cont'd

- Available information
- Using a high level of professional judgment in making decisions based upon information

Similarly, the document suggests that evaluation involves teachers and others in analyzing and reflecting upon information about student learning gathered in a variety of ways. The process requires:

- Developing clear criteria and guidelines for assigning marks or grades to student work
- Synthesizing information from multiple sources
- Weighing and balancing all available information
- Using a high level of professional judgment in making decisions based upon information

Assessment and evaluation in Design and Fabrication 2202 must consider both the problem-based learning approach used and the required General Curriculum Outcomes (GCOs) outlined in the Atlantic Canada Foundation document on Technology Education. The assessment strategies recommended in section IV of this guide reflect these requirements.

Program Design and Components

Program Components

Design and Fabrication 2202 is the second of two design and fabrication courses that are included in the new Skilled Trades and Technology program for Level I, II, and III high school students in Newfoundland and Labrador. This two-term course reinforces and extends on the basics of engineering design, fabrication processes and shop safety covered in Design and Fabrication 1202. Although not a required prerequisite, completion of Design and Fabrication 1202 is recommended before commencing studies in Design and Fabrication 2202.

The Skilled Trades and Technology program was introduced by the Division of Program Development, Department of Education, in 2006, based on the recommended model for K-12 technology education presented in the Atlantic Canada Foundation document for Technology Education (2001). This new program replaces the former Industrial Arts program and offers students a modernized curriculum that reflects current industry practice in a variety of trades and technology areas.

Design and Fabrication 2202 introduces students to the advanced technologies being used today in engineering design and manufacturing including 2D and 3D Computer Aided Design and Drafting (CADD) software, Computer Aided Manufacturing (CAM) software and Computer Numerical Control (CNC) machining. Through participation in group labs and the major group Design Project, students also learn the value of the collaborative approach to problem-solving in engineering and manufacturing.

Outcomes Structures

The course curriculum is structured to address outcomes as suggested in the Atlantic Canada Foundation document on technology Education (2001). These include Essential Graduation Learnings (EGLs), General Curriculum Outcomes (GCOs), Key Stage Curriculum Outcomes (KSCO) and Specific Curriculum Outcomes (SCO).

EGLs are statements describing the knowledge, skills, and attitudes expected of all students who graduate from high school.

GCOs are statements that identify what students are expected to know and be able to do upon completion of study in a curriculum area.

KSCO provide additional detail for each of the GCOs and provide a means to quickly assess progress in a subject area at the end of a level of schooling. SCO identify what students are expected to know and be able to do at a particular grade level.

Essential Graduation Learnings

The EGLs specified in the Atlantic Canada Foundation document on Technology Education include:

Aesthetic Expression

Graduates will be able to respond with critical awareness to various forms of the arts and be able to express themselves through art.

Citizenship

Graduates will be able to assess social, cultural, economic, and environmental interdependence in a local and global context.

Communication

Graduates will be able to use listening, viewing, speaking, reading, and writing modes of language(s) and mathematical and scientific concepts and symbols, to think, learn, and communicate effectively.

Personal Development

Graduates will be able to continue to learn and to pursue an active, healthy lifestyle.

Problem Solving

Graduates will be able to use strategies and processes needed to solve a wide variety of problems, including those requiring language, and mathematical and scientific concepts.

Technological Competence

Graduates will be able to use a variety of technologies, demonstrate an understanding of technological applications, and apply appropriate technologies for solving problems.

Spiritual and Moral Development

Graduates will be able to demonstrate understanding and appreciation for the place of belief systems in shaping the development of moral values and ethical content.

General Curriculum Outcomes

The GCOs for technology education as defined in the Atlantic Canada Foundation document on Technology Education include:

GCO 1: Technological Problem Solving

Students will be expected to design, develop, evaluate, and articulate technological solutions.

GCO 2: Technological Systems

Students will be expected to evaluate and manage technological systems

GCO 3: History and Evolution of Technology

Students will be expected to demonstrate an understanding of the history and evolution of technology, and of its social and cultural implications.

GCO 4: Technology and Careers

Students will be expected to demonstrate an understanding of current and evolving careers and of the influence of technology on the nature of work.

GCO 5: Technological Responsibility

Students will be expected to demonstrate an understanding of the consequences of their technological choices.

Key Stage Curriculum Outcomes

GCO 1: Technological Problem Solving

The KSCOs for Design and Fabrication 2202 are based on the five previously noted GCO's and indicate what is expected of students at the end of Level III. By the end of Level III, students will be expected to:

- [1.401] articulate problems that may be solved through technological means
 - assess diverse needs and opportunities
 - construct detailed design briefs that include design criteria and a work schedule

- [1.402] conduct design studies to identify a technological solution to a problem
 - investigate related solutions
 - document a range of options to solve this problem
 - determine and justify the best option
 - determine resource requirements and availability
 - develop detailed action plans, including technical drawings and sequences of action

- [1.403] develop (prototype, fabricate, make) technological solutions to problems
 - match resources and technical processes for specific tasks
 - construct and test models and prototypes as needed
 - construct the solution with adherence to the design criteria
 - document activities, decisions, and milestones

- [1.404] critically evaluate technological solutions and report their findings
 - develop detailed evaluations of both their own and others' technological solutions, with reference to independently developed criteria
 - employ a continuous assessment methodology with the purpose of continuous improvement of the design
 - document and report their changes, the rationale for change, and conclusions

- [1.405] communicate ideas and information about technological solutions through appropriate technical means
 - accurately present technical information by using a representative sample of analog and digital tools, including, for example, two- and three-dimensional, computer-assisted drafting and modeling tools
 - create accurately scaled models and prototypes

GCO 2: Technological Systems

- [2.401] operate, monitor, and adjust technological systems of increasing complexity
- [2.402] manage technological systems of increasing complexity
- [2.403] modify programming logic and control systems to optimize the behaviour of systems
- [2.404] deconstruct complex technological systems into their simpler systems and components
- [2.405] troubleshoot and maintain systems

GCO 3: History and Evolution of Technology

- [3.401] evaluate technological systems in the context of convergence where one system has multiple functions, or divergence where multiple systems have the same function
- [3.402] evaluate the symbiotic roles of technology and science in modern society
- [3.403] analyse the symbiotic relationship between technology and education, including factors that influence standards for technological literacy and capability, and ways that the community responds
- [3.404] critically evaluate the effects of accelerating rates of technological change on self and society
- [3.405] account for effects of cultural diversity on technological solutions
critically examine the effects of cultural diversity on market forces and technological products, and vice versa
incorporate knowledge of cultural diversity into development of technological solutions

GCO 4: Technology and Careers

- [4.401] assess and evaluate employability profiles for a variety of workplaces and careers and determine the level of technological literacy and capability they would need to achieve for job entry
- [4.402] employ design and invention as tools to create entrepreneurial activity
- [4.403] envision their short- and longer-term future and develop a plan for acquiring the technological literacy/capability required to achieve their vision

GCO 5: Technological Responsibility

- [5.401] demonstrate responsible leadership in employing legal and ethical rules and principles
- [5.402] demonstrate responsible leadership in employing health and safety rules and standards
- [5.403] demonstrate responsible leadership in taking proper measures to manage current and future technological risk

Unit 1

Engineering Design and Manufacture

Purpose

UNIT 1 helps students recognize the interrelation between engineering design and manufacturing, and thereby provides the foundation for this course. Students also learn the main steps in the CAD/CAM process, develop the problem definition for the group Design Project, and determine the Design Portfolio requirements through completion of the following sub-units:

- 1.1 The Engineering Design Process (2 hours)
- 1.2 The Design Project and Design Portfolio (2 hours)
- 1.3 Design for Manufacturing and Assembly (3 hours)
- 1.4 Overview of the CAD/CAM/CNC Process (1 hour)
- 1.5 Design Project (2 hours)

Profile

The relationship between engineering design and manufacturing is a critical consideration for both the designer and the manufacturer. Designers must consider the constraints imposed by manufacturing technologies, operator skills and material properties. This need for a team approach is reflected in the group Design Project. Students, working in groups of 2, will follow the actual CAD/CAM process in completing the engineering and manufacture of a design prototype.

Implementation

Unit 1 introduces the primary topics of study for the remainder of the course and establishes the basis for a cooperative problem-based approach to learning. The teacher should encourage an interactive co-operative learning environment in which each student is given the opportunity to actively participate. An emphasis should be placed on students “learning by doing” with the teacher taking on the role of facilitator.

Evaluation

Unit 1 consists of 10 hrs of instruction, which represents approximately 9% of the total course teaching time.

This unit forms the basis of the remainder of the course and evaluation of this section should reflect that. It is expected that many of the assessments in this section will be carried on into later units.

Topic 1: The Engineering Design Process

Outcomes

Students will be expected to

1.1.1 Identify the steps in the design process [1.401]

Delineation

The discussion should focus on:

- Needs identification
- Defining the Problem
- Generating Options
- Selecting the Best Option
- Developing the Solution
- Prototyping and Testing
- Evaluation and Redesign

Elaborations - Strategies for Teaching and Learning

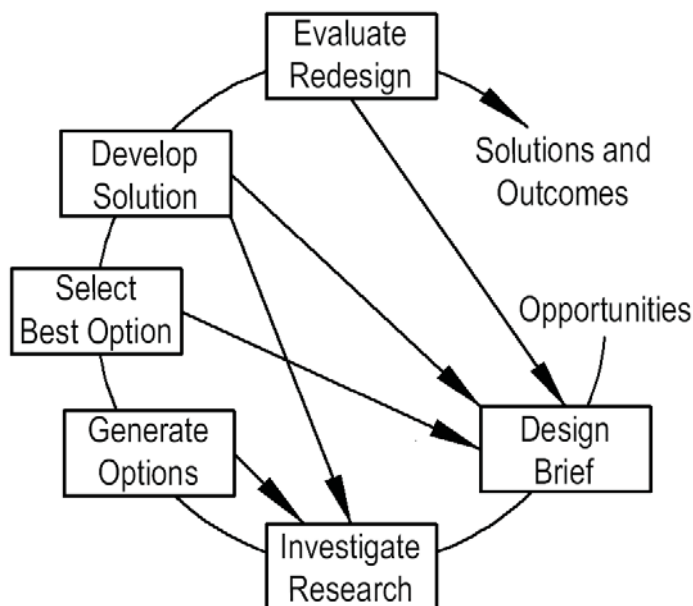
Teacher Preparation

It is essential in any design that the student be familiar with the steps in the design process and their relation to the fabrication of the system or product.

Using a case study example, the teacher should discuss the product life cycle or how a product or system starts as an identified need that evolves through the design process to a built prototype.

The teacher must also introduce the concept of problem solving in both individual and group environments and the related advantages/disadvantages in each case.

The Design Process can be encapsulated in the following diagram.



The parts of the process are:

- The Design Portfolio - the design portfolio is essentially a diary of the project progress and contains all relevant information, especially trial and error information
- Defining the Problem - At this juncture students develop a problem statement, design objectives and related criteria while identifying design constraints
- Generating Options - Students develop alternative solution

Topic 1: The Engineering Design Process

Suggested Assessment and Evaluation Strategies

Paper and pencil

- Students could develop a poster outlining the steps of the design process. This poster could be decorated with examples of the various stages of a product in design.

Presentation

- Students could present to the class their interpretation (based on student vernacular) of the design process.

Paper and pencil

- Students could outline and explain the steps of the design process. This outline should include language such that a student in grade 4 or 5 would understand what was being explained.

Discussion

- Students could debate and discuss the order of the steps of the design process. Links to the scientific method and other problem-solving approaches should be introduced here.

Design Portfolio

- Students could create a design portfolio at this point. This portfolio will contain all of the designs, design elements, meeting notes and drawings that students will have undertaken in this course. The portfolio could be paper-based, digital or some other media that students will feel comfortable reporting in.

Resources

Topic 1: The Engineering Design Process

Outcomes

Students will be expected to

1.1.1 Identify the steps in the design process [1.401]

Delineation

The discussion should focus on:

- Needs identification
- Defining the Problem
- Generating Options
- Selecting the Best Option
- Developing the Solution
- Prototyping and Testing
- Evaluation and Redesign

1.1.2 Apply the design process in the design of a simple project [1.402, 1.403]

Elaborations - Strategies for Teaching and Learning

concepts

- **Selecting the Best Option** - Alternative solutions should be evaluated in terms of design objectives and the best alternative selected.
- **Developing the Solution** - Develop a production plan for prototype fabrication, which will include detail and assembly drawings for the prototype.
- **Prototyping and Testing** - The design prototype is fabricated at this point so that testing of the design prototype can take place.
- **Evaluation and Redesign** - The prototype is evaluated in terms of design objectives and testing. Required design modifications resulting from the evaluation should take place here.

Teacher Preparation

Once the student knows the steps used in the design process the process needs to be reinforced through application. In this section the teacher should review the design of the product discussed in the previous class and the steps followed in the design process.

The teacher should emphasize to the students the importance of developing a problem definition including objectives, criteria and constraints.

It is understood that the design should involve at some point the use of CNC in its fabrication. This project could easily form the basis of instruction in upcoming objectives and will be referred to frequently in the following pages.

Topic 1: The Engineering Design Process

Suggested Assessment and Evaluation Strategies

Resources

Practical activity

- Students could design their first project in small groups at this stage. It is suggested that the design be very simple and be significantly facilitated by the instructor.

Paper and pencil

- Using the poster created for the last outcome, students could outline how their process fits into and matches the design process. If the poster was not created, then a simple comparison to the steps of the Design Process outlined in class will be sufficient. This can be done as a written assignment or poster and could be used as a check and balance to ensure that the process was followed

Topic 2: The Design Project and Design Portfolio

Outcomes

Students will be expected to

- 1.2.1 List the requirements of the design portfolio (1.405)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

The design of a product and the associated activities such as research, meetings, evaluations and so on are ongoing activities and the design team has to keep records. The teacher should explain that students will be required to complete a design portfolio as they progress through the project.

As stated in the Atlantic Canada Foundation document on Technology Education, the design portfolio is essentially a diary of the project progress and contains all relevant information, especially trial and error information. It is used to illustrate the thinking and planning processes that students engage in while developing a technological solution to a problem. Assessment of this process is often indirect, in that the evidence comes from a variety of sources. The value of the portfolio depends on how well it represents this process.

As a first step in developing the design portfolio, the student groups will be required to write a design brief. As stated in the Atlantic Canada Foundation document on Technology Education, the design brief is negotiated between student and teacher and sets the conditions under which the student engages in a design activity. While design professionals are assessed mainly on the solution to the problem, students are assessed mainly on growth in their design capability.

Suggested Student Activity

In groups of 2 or 4, students should prepare the outline for a design portfolio. This outline should contain the design brief, title of the project selected, client (teacher's name), project location, and members of the design team (student group). As the students progress through the unit, their portfolios will be updated as directed by the teacher.

Topic 2: The Design Project and Design Portfolio

Suggested Assessment and Evaluation Strategies

Portfolio

- Students could begin their design portfolio at this time. This is a separate portfolio from the digital portfolio the students have put their work into up to this point.
- Students could develop their project ideas at this point. Although the problem statement occurs next, some idea of what the project will entail should be a part of developing the problem statement

Group Work

- Students will work in small groups to develop the design brief. This will include meetings as a group, interviews with the teacher and is expected to be an ongoing process.

Research Assignment/Presentation

- Students could research the origins and evolution of the design process. This could entail a written assignment, a presentation to the class or a timeline poster to be displayed.

Paper and pencil

- Students could create a graphic to represent the design process. This could be done as a flow-chart to accurately depict the various stages and paths such a process will take.

Resources

Topic 2: The Design Project and Design Portfolio

Outcomes

Students will be expected to

1.2.2 Identify Design Project critical activities [1.401]

Elaborations - Strategies for Teaching and Learning

As the portfolio is a record of all activities that will be undertaken in the design process, there also must be planning to start the process. In any fabrication or design activity the safest and best way to undertake a task is to lay out and plan the entire activity from start to finish. The critical activities are those which must be accomplished for the project to be a success.

The design process gives us some of these activities:

- Generating Options
- Selecting the Best Option
- Developing the Solution
- Prototype creation and Testing
- Evaluation and Redesign

Options must be generated after the design problem is identified. One option must be selected so that the process can continue. That option is then used to develop the solution and the fabrication of the solution is necessary for testing and evaluation to occur. Finally after all this is completed, redesign taking into account the results of the testing will help create the best solution.

Each of these tasks should be laid out and planned for. Although the general aspect of the process if described above each task breaks down into smaller more specific tasks. For example, if the problem statement is to develop a numbering system for the school including a design for door numbers. The steps of the process will involve:

- Soliciting opinions of the school population;
- Researching the best way to make room numbering more visible and logical;
- Developing design constraints such as the size of the numbering and material is should be made out of;
- Identifying design objectives in that the numbering will allow for ease of finding rooms and assignment of empty classrooms;
- Developing solutions from the constraints and objectives;
- Selecting the best solution and
- Fabricating a prototype that can be placed on a door... and so on.

Each of those steps is critical to the process.

Topic 2: The Design Project and Design Portfolio

Suggested Assessment and Evaluation Strategies

Discussion

- Students could discuss what they consider to be the critical tasks and how each one will interact. This discussion should also include how much time will be taken up with each task.

Paper and Pencil/Presentation

- Students could itemize the critical tasks and using a concept map or flowchart show how each one is interrelated and interdependent. This can be done as a group exercise and be presented to the class as a whole either as a presentation or in a poster format.

Research

- Students could research a variety of designed products and attempt to identify what the critical activities would have been in the process of designing the product in question. This can be done as an assignment to be placed in their portfolio or as a presentation to the class as a whole.

Design portfolio

- Students could place an overview of these concepts into their design portfolio.

Resources

Topic 2: The Design Project and Design Portfolio

Outcomes

Students will be expected to

- 1.2.3 Develop a schedule for completion of project activities [1.402, 1.403]

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Within the design for manufacturing area scheduling may be the most difficult and limiting factor in the fabrication process. The fabrication facility may be limited by the number of machines or qualified operators it has to complete projects. Usually a business would identify these potential bottlenecks and either expand its equipment base or personnel to adjust for the problem. In some instances, the only affordable way to deal with the potential problem is to schedule around it.

With only a single CNC machine available for student use, and a limited number of CAM posting seats this will be the case here. This provides an excellent teachable moment by involving students in the scheduling.

Scheduling involves looking at what has to be done, the time frame it has to be done in, and how much time each individual task will take. There are two types of tasks when looking at scheduling, and in this instance we will use an analogy from electricity and call them series and parallel. A series task is one that has to be completed in a certain order. One task builds on the previous and then the next task builds on it. These are likened to step-by-step instructions. A parallel task is one that can be completed while another is also being done. They are interlinked but not sequential.

In the previous section students were asked to identify the critical activities to be completed in the process. Each of those activities will form the basis of the schedule to be developed. Special attention should be given to those activities that may be able to be done in parallel, such that total time can be saved. In the previous example, the research into door numbers and the soliciting of opinions from the school as a whole can take place at the same time. Determining size constraints and materials can also be done in parallel.

All of the competing design elements can also be done at the same time, as a solution is being determined, examples of what the various solutions will look like can be done in parallel for the final decision. It is through this careful planning that CNC Machinery has limited down time and bottlenecks are avoided.

Topic 2: The Design Project and Design Portfolio

Suggested Assessment and Evaluation Strategies

Discussion

- Students could discuss what they consider to be the critical tasks and how each one will interact. This discussion should also include how much time will be taken up with each task.

Paper and pencil

- Students could create a flowchart that illustrates how the critical tasks interact with one another to help identify parallel and series tasks..

Presentation

- Students could present to the class how their scheduling will ensure that no bottlenecks will occur and the amount of idle time will be reduced.

Design portfolio

- Students could place an overview of these concepts into their design portfolio.

Resources

Topic 3: Design for Manufacturing and Assembly

Outcomes

Students will be expected to

- 1.3.1 Explain the relationship between product design, manufacturing and assembly [1.403]
- 1.3.2 Demonstrate a recognition of the importance of a team approach in design, manufacturing and assembly [4.401]

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Engineering design must consider the limitations imposed by time, cost, and physical constraints. The capability of manufacturing equipment and/or equipment operators, for example, may limit the tolerance to which parts can be manufactured. Designs which don't initially consider the capability of manufacturing must be reworked and this can increase both cost and time to completion. During the design process the designer has to consider the available manufacturing processes in view of cost and time constraints. The principles governing Design for Manufacture (DFM) and Design for Assembly (DFA) should be incorporated to facilitate manufacture.

The teacher should review the DFM/DFA principles and discuss these with the students, using some common products to illustrate. The primary aim of Design for Manufacturing (DFM) is to minimize the cost of production and/or time to market for a product, while maintaining an appropriate level of quality. This typically involves minimizing the number of parts in a product. Similarly, Design For Assembly (DFA) involves making attachment directions and methods simpler. There are several fundamental principles governing DFM and DFA that are outlined in the teacher's resource guide.

Teacher Preparation

Design and fabrication of a product has gone from the traditional one-person operation to a team approach. The design and fabrication of a product or system now involves a multidiscipline team of technical specialists, accountants, purchasers, marketers and legal experts. All of these individuals have input on different areas of the design. A common example would be the design of a car. Historically students can also relate this concept to the creation of the assembly line.

Working in groups students will be able to experience the team approach first hand.

Points to emphasize

- Design of some products involve design of their component parts and then assembly. This can be related to the solids design software used later in this course.
- Assembly can also be done in components as in an assembly line.
- The adage "sometimes the whole is greater than the sum of its parts" has relevance in this section, as working together can create something greater than each group working in isolation.

Topic 3: Design for Manufacturing and Assembly

Suggested Assessment and Evaluation Strategies

Paper and Pencil/Role Play

- Students could plan out their fabrication discussed in the previous outcome. When doing so they could consider issues of assembly and manufacturing which could hinder the process as a whole.

Research/Presentation

- Students could research the principles of DFA and DMA and present them to the class as a whole. In doing so it would be expected that they would put the concepts into their own words.

Design portfolio

- Students could place an overview of these concepts into their design portfolio.

Discussion

- Students could discuss what the meaning of the adage “the whole sometimes exceeds the sum of its parts”. This discussion could include how this relates to the design and fabrication process.

Paper and pencil

- Students could itemize the benefits of team work in the process of design and fabrication. Examples from history of designs that were not carried through to fruition should be included in this assignment.

Presentation

- Students could present to the class how teamwork is important of the design and fabrication process.

Resources

Topic 3: Design for Manufacturing and Assembly

Outcomes

Students will be expected to

- 1.3.3 List at least 3 of the main principles governing good design for manufacturing and assembly (DFMA) [1.403]

Elaborations - Strategies for Teaching and Learning

The primary aim of Design for Manufacturing and Assembly (DFMA) is to minimize the cost of production and/or time to market for a product, while maintaining an appropriate level of quality. This typically involves minimizing the number of parts in a product. Similarly, Design For Assembly (DFA) involves making attachment directions and methods simpler. There are several fundamental principles governing DFM and DFA including:

- Minimize part count by incorporating multiple functions into single parts. Several parts could be fabricated by using different manufacturing processes (sheet metal forming, injection molding). Ask yourself if a part function can be performed by a neighboring part.
- Modularize multiple parts into single sub-assemblies.
- Design to allow assembly in open spaces, not confined spaces. Do not bury important components.
- Parts should easily indicate orientation for insertion. Parts should have self-locking features so that the precise alignment during assembly is not required. Or, provide marks (indentation) to make orientation easier.
- Standardize parts to reduce variety.
- Design parts so they do not tangle or stick to each other.
- Distinguish different parts that are shaped similarly by non-geometric means, such as color coding.
- Design parts to prevent nesting. Nesting is when parts are stacked on top of one another clamp to one another, for example, cups and coffee lids.
- Design parts with orienting features to make alignment easier.
- Provide alignment features on the assembly so parts are easily oriented.
- Design the mating parts for easy insertion. Provide allowance on each part to compensate for variation in part dimensions.
- Design the first part large and wide to be stable and then assemble the smaller parts on top of it sequentially.
- If you cannot assemble parts from the top down exclusively, then minimize the number of insertion direction. Never require the assembly to be turned over.
- Joining parts can be done with fasteners (screws, nuts and bolts, rivets), snap fits, welds or adhesives.

Topic 3: Design for Manufacturing and Assembly

Suggested Assessment and Evaluation Strategies

Discussion

- Students could discuss the listed DFMA principles and decide which would be applicable to their own design and fabrication project.

Paper and pencil

- Students could encapsulate the principles outlined in their own words, describing them such that someone of 12 years of age could understand them.

Presentation

- Students could present to the class how considering these principles is important of the design and fabrication process.

Design portfolio

- Students could place an overview of these concepts into their design

Resources

Topic 4: Overview of the CAD/CAM/CNC Process

Outcomes

Students will be expected to

- 1.4.1 List the main steps that comprise the CAD/CAM/CNC process from product concept to finished product[1.403]

Elaborations - Strategies for Teaching and Learning

The CAD/CAM process enables the seamless progression from design concept to finished product without the need for the traditional engineering blueprint for interpretation by shop personnel. Currently available Computer Aided Drafting and Design (CADD) software extends on traditional 2D CAD tools by enabling the development of 3D virtual prototypes that can be animated to test functionality, analysed to assess strength, and then imported into Computer Aided Manufacturing (CAM) software. CAM software available today facilitates the multiple tool definitions and complex toolpaths that must be specified in the part program used to control Computer Numerical Controlled (CNC) machining systems.

In sequential order the process can be identified as follows:

- The first step is the design, which may start out as a sketch. From this a rendering in a CAD program is made. This drawing is much more precise than the sketch and includes all of the information necessary to produce the product as a whole. The CAD drawing completes the first element of the process.
- The next step is CAM. CAM stands for Computer Aided Manufacturing, and involves a specific program to aid in this endeavour. The CAM package plots the tool paths, defines the tools and basically lays out what will happen on the CNC machine. It usually does this in a graphical form, and may include elements of design in its programming. The CAM package plots how the tools will move, what they will do and how they will do it. It does all that and also converts the end product into what is called G&M code.
- We have now moved onto the CNC element of the process. The G and M code is transferred to the CNC machine, and the program is ready to run. There are some steps for preparation though. Even though the CAM program has set the tool paths and decided how things will run from there, it does so from a specific zero point. The CNC machine must be “zeroed” to that point before the program can run and the product created. As well the stock must be secured in the proper location and prepared to take the tool. Finally in some CNC machines (such as ours) the proper tool must be placed in the collet. Once that is finished the process is complete and the product is ready to run.

Three elements creating a single process and product.

Topic 4: Overview of the CAD/CAM/CNC Process

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could prepare a drawing that could be transferred to a CAM program. This drawing must be in a format that is accepted by the CAM software.

Research/Presentation

- Students could research the origins of G and M codes and why they are used in CNC machines. A short presentation to the class or a poster for display could be developed with the information found.
- Students could also research the origin of CNC machining as a whole and discuss the possible reasons it was invented. Comparisons between the CNC available today and in the past should be made.

Practical Activity

- Students could examine the software and hardware that is used in this process. They should be able to identify the different types of software to be used and the methodology of inputting files and information into the equipment available.

Design Portfolio

- Students could put the relevant information about G and M codes and CAM software into their portfolios.

Resources

Topic 5: Design Project

Outcomes

Students will be expected to

- 1.5.1 Develop a problem statement (1.401)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

The development of a problem statement is the initial and probably most important part of the design process. The problem statement focuses the team and delineates the broad parameters of the design process. Any design project is the result of a perceived need for a product. That need may relate to the requirement to upgrade or improve an existing product or system, or to fulfill a consumer requirement for a new system or product.

The teacher should define the need for a product and then work with the individual groups to help them define the problem statement. For example the teacher could pose a problem involving creation of a numbering system for the school building. After a discussion of the problem and examination of existing systems, they would develop a problem statement indicating what it is that they propose to do to resolve the numbering challenge.

As an activity, the teacher could also have students work to define a perceived need. In industry tools such as polls and customer surveys are used as a means to identify new products. In a school sense the students could poll their peers, put out a questionnaire to staff and students or hold focus groups to find out what the school feels is a need. It should be noted that this should be a fairly restrictive process offering a choice of things that students are able to accomplish within the fabrication lab. The previous example of a numbering system for the school could present what materials it could be made out of, how big it should be, where the numbering should start and how special rooms should be identified. If this is to be a major design project involving the whole class then the scope of what will be done should reflect this. If on the other hand the design project will involve a series of groups then the scope can be significantly reduced.

Any number of projects can be started at this point. It is only when the limitations of time and availability of equipment enter the picture in the following objectives that a limit may need to be placed. This activity can be undertaken as a whole group or in small student groups.

Topic 5: Design Project

Suggested Assessment and Evaluation Strategies

Practical Activity

- In groups students could develop a problem statement as the first step towards developing a product in this design process.

Design Portfolio

- Students could put the research and background material they used to develop their problem statement in their design portfolio.

Discussion

- Students could develop a questionnaire or focus group to discuss with their peers and teachers some things that could be produced to make things better in their school. The results of such a discussion could form the basis of the problem statement.

Research/Presentation

- Students could research other problem-solving approaches (such as the scientific method) and their similarities to the design process. A poster comparing and contrasting these methods could be placed in the Design and Fabrication labs.

Resources

Topic 5: Design Project

Outcomes

Students will be expected to

- 1.5.2 Develop design objectives and related criteria. (1.401, 5.401, 5.402, 5.403)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Following the development of a problem statement the design team has to develop a set of measurable objectives that the design must meet. For each objective or design goal, corresponding criteria must be assigned that quantify or qualify the degree to which the objective must be met. For example, the objective “The signage used on doors in the school for numbering must be clearly visible” could have the associated criteria “Must have some glow-in-the-dark capability”.

The teacher should emphasize the need for measurable criteria where possible. In some cases, quantifying an objective in this manner is not possible and the criteria may be a qualifier. For example, the objective “The numbering system design must be aesthetically pleasing” could have the associated criteria “Must be approved by a review panel comprised of student, staff and school board representatives”. The teacher should also point out to the students that objectives are not static and may change as the project progresses.

For the more practical in school projects, the measurable criteria should be determined by the stakeholders, the students and teachers. So if the project is to be classroom numbering system then there are certain logical things that have to be accomplished.

- Such a system needs to be logical.
- Begin and end at specific points.
- Represent classroom use as well as position in the building.
- Be clearly visible.
- Encompass a wide variety of needs in the school as a whole.

The stakeholders in this instance may also look for it to blend into the decor of the building, be aesthetically pleasing etc.

From the teacher and student perspective the system and the numbers themselves must be superior to what is already there and give the students opportunities to apply the skills they will learn in this course to their design and fabrication. This will also be encompassed by the materials chosen for the fabrication.

Topic 5: Design Project

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could develop measurable criteria whereby their products can be measured against. This could be done in a large group or small group setting, but should have some teacher input.

Discussion/Presentation

- Students could present their measurable criteria to the class as a whole and take input from group discussions. This will help to refine the criteria and make the process more effective.

Research/Presentation

- Students could research a product development and outline the steps concerning the measurable criteria. This research would involve online searching and maybe some industry contact.

Design Portfolio

- Students could put the research and background material they used to develop their measurable criteria in their design portfolio.

Resources

Topic 5: Design Project Problem Definition

Outcomes

Students will be expected to

1.5.3 Identify design constraints
(1.401)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Most design projects have constraints that limit the solution options available to the design team. Constraints are generally classified as physical, cost or time constraints. An example of a physical constraint relating to the school numbering system, for example, would be that the numbers must fit on a conventional 36" doorways. A cost constraint could be that the numbers must be made of a material that is reasonably cost effective. A time constraint could be that the design project must be completed within 3 months.

These design constraints will have a significant impact on what is finally produced, especially if the project is one suggested by staff and students.

- **Costs:** this will have to be negotiated with the teacher and perhaps the administration. A ballpark figure would be what a commercially made product would cost.
- **Size:** the final product must be able to fit out the door of the fabrication lab or fit out in pieces. This is a significant design constraint for many things created in this space.
- **Time:** depending on the length of the project this will be limited by the amount of class time and the length of the school year. This can be modified by making time available after school for the completion of certain aspects, but working within constraints is a good practice.

The teacher should discuss the three types of constraints and give examples where there are physical, cost and time limitations that impact design.

In this instance identifying constraints could either be a whole class activity or be done in the smaller student groups. This is once again reliant on the type of projects being undertaken. Time would be the largest constraint at this point. How much time is in the course and how much "face-time" the students will have with the CNC machine. If there are multiple projects competing for the same manufacturing resources then this may limit either the size of the number of such projects.

Topic 5: Design Project Problem Definition

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could develop the design constraints for their project. This could be done in a large group or small group setting, but should have some teacher input.

Discussion/Presentation

- Students could present design constraints to the class as a whole and take input from group discussions. This will help to refine the constraints and make the process more effective.

Research/Presentation

- Students could research a product development and outline the design constraints involved in this development. This research would involve online searching and maybe some industry contact.

Design Portfolio

- Students could put the research and background material they used to develop their design constraints in their design portfolio.

Resources

Unit 2

CNC Programming Basics

Purpose

UNIT 2.0 introduces students to basic Computer Numerical Control (CNC) programming using G and M codes and a text editor. This unit is considered a prerequisite to using the shop CNC machine in UNIT 4.0 and completing UNIT 5.0 on CAM. Students learn the basic format of CNC programs and the common G and M codes used to control operation of a CNC machine through completion of the following sub-units:

- 2.1 Overview and History of CNC Machines
- 2.2 General CNC Machine Types and Applications
- 2.3 CNC Programming - G & M Codes
- 2.4 Lab Exercise - CNC Part Program using NC Software
- 2.5 Lab Exercise - Design Project CNC Considerations

Profile

Students are not expected to develop proficiency in CNC programming through completion of UNIT 2.0. Following completion of this unit, students will be able to summarize the historical development of CNC machines, identify industrial applications of CNC, illustrate the function of CNC programs in the CAD/CAM process, and write a basic CNC program using a text editor.

Implementation

Delivery of UNIT 2.0 will occur primarily in the computer lab and/or fabrication lab. The Internet will be used in support of 2.1 and 2.2 while 2.3 to 2.5 will require use of a text editor or a freeware CNC programming simulator. Students should work in groups to complete the lab exercises. Students should recognize that the CNC program requirements for the Design Project would be too difficult to write manually and, thus, CAM software will need to be used.

Evaluation

Unit 2 consists of 15 hrs of instruction, which represents approximately 12% of the total course teaching time.

Topic 1: Overview and History of CNC Machines

Outcomes

Students will be expected to

- 2.1.1 Identify the major events in the historical evolution of CNC machines [3.404]

Elaborations - Strategies for Teaching and Learning

Numerical control (NC), which was the pre-cursor to today's CNC, was developed in the early 1950s to make it possible for large quantities of the desired components to be very precisely and efficiently produced (machined) in a reliable repetitive manner. An NC machine is essentially a machine that automatically operates in response to coded instructions it receives from its processing unit. Early NC machines were fed instructions using paper tape or punch cards. A timeline of the development of NC is shown below.

- 1700's
 - punch cards control automatic knitting machines.
- 1800's
 - player pianos developed, using perforated rolls of paper
 - jigs and fixtures for manufacturing developed
 - emphasis on mass production
- 1940's
 - introduction of hydraulic, pneumatic and electronic controls. Automatic machining becomes emphasis, with mass production experiments into NC
- 1950's
 - research and development into NC with new models developed in the 1960's.
- 1970's
 - range of applications expanded for NC, computers begin to be used for inputs and machining centres expanded.

The basics of the machine used in CNC has not changed substantially since that time, although the controllers and computers interfacing with them have. The computer processes the instructions needed to control the NC machine written in the form of a CNC program. CNC programs consist of a series of coded instructions referred to as G and M codes that control the motion and actions of the machine.

Topic 1: Overview and History of CNC Machines

Suggested Assessment and Evaluation Strategies

Paper and pencil/Presentation

- Students could research using the internet to develop a timeline to trace the development of the major events in the historical evolution of CNC machines. This can be produced as a poster or done as a class presentation.

Presentation

- Students could develop a digital slideshow to present to class that illustrates events in the historical evolution of CNC machines. Within this slideshow they could encompass the other major events in computing that have led to the final evolution of CNC.

Research/Assignment

- Students could research another technology and its evolution over the same time period as CNC. In this research, specific emphasis on the speed of the evolution of the technology in the last 50 years should be given precedence. This then could be compared to the CNC evolution over the same time period.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

Topic 1: Overview and History of CNC Machines

Outcomes

Students will be expected to

- 2.1.2 List the advantages\ disadvantages of CNC machining when compared to traditional manual machining [1.401, 1.403]

Elaborations - Strategies for Teaching and Learning

The previous section outlined the evolution of numeric control and through the outlined indicated a series of reasons why NC has been used and where CNC was developed. The same sort of advantages that created numeric control would also encompass the reasons we use CNC today:

- Repeatability. Once the part is machined it can be repeated as many times as needed.
- Precision. CNC machines are capable of very precise machining, which added to their repeatable make them valuable tools.
- Accuracy. The part machined will be the exact same each time. This assumes the use of jigs to insure proper placement, but easily could occur in the mass production machine environment.
- Training. You do not need to be a machinist to operate a CNC machine, although you need to be trained in its use. The program to certify a CNC Operator is significantly less than the apprentice program for a machinist.
- Speed. A CNC machine operates at a much higher and continuous rate than a human being. Once the program is loaded the CNC machine can go 24 hrs. a day 7 days a week, producing intricate parts in hours it may take a machinist days to make by hand.
- Flexibility. Programs can easily be loaded and altered. Retooling to create a different part by hand may take some time, but when using CNC it could be as simple as changing a bit, and with an automatic tool changer it could occur without any intervention or touch by human hands.

Disadvantages of CNC Machining

- Expense. For high-end applications CNC machines can cost as high as \$ 1 000 000. They may pay for themselves over time but this high start up cost makes them rarely seen in many manufacturing companies even today.
- Personnel. With the lessened training requirements for operators, the variety of skills that a machinist has would be lost to the company.
- Size limitations. The size of the part is limited to size of machine. Even the more expensive machines are limited in this.

Topic 1: Overview and History of CNC Machines

Suggested Assessment and Evaluation Strategies

Paper and pencil

- Students could research using the internet to create a table to illustrate the advantages and disadvantages of CNC machining compared to traditional manual machining

Presentation

- Students could develop a short presentation that illustrates the advantages and disadvantages of CNC machining. This can be done by using poster paper or digital software.

Discussion / Presentation

- Class could be divided into small groups that discuss the advantages and disadvantages of CNC machining; they could then present their findings to the class.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

Topic 1: Overview and History of CNC Machines

Outcomes

Students will be expected to

- 2.1.3 Describe the basic operation of CNC machines [2.404]

Elaborations - Strategies for Teaching and Learning

The original use of numerical control (NC) machines was to enter a series of instructions using an input device and then have the machine carry them out. With the advent of computer technology the input device standardized, and as the capabilities of computers increased the focus of the NC became the computer. In most instances there are actually two computers involved in the process. One is the computer that carries out the function as outlined in the CAD/CAM/CNC process introduced in unit one. The second computer, usually called a controller, is the one that actually interfaces with the machine and “controls” its movements. In this instance we will be focusing on what occurs in the CNC machine itself.

CNC machines are computer controlled. In order to operate a CNC machine a computer program is generated through a piece of software that enables a machine tool to be moved in different directions. The computer reads and deciphers the G and M codes from a computer program that is generally created through the use of a CAM (Computer-aided manufacturing) software. The part that is being manufacture will depend on the type of CNC machine that will be used.

A G01 code, for example, would instruct the machine to move in a straight line while an M03 code would instruct the machine to turn on its spindle.

Through an interactive discussion, the teacher should overview the historical evolution of the CNC machine with a view to identifying the primary advantages of this technology that have stimulated its evolution and the disadvantages that have limited its exclusive adoption in machine shops. The basic operation of a CNC machine would ideally be demonstrated using the shop CNC machine.

Topic 1: Overview and History of CNC Machines

Suggested Assessment and Evaluation Strategies

Paper and pencil

- Students could research and write a report on the basic operation of CNC machines. Students should research how the machine is controlled by the software that enables the CNC machine to move in the direction it is programmed to move.

Presentation

- Students could create a presentation that illustrates the basic operation of CNC machines. Students can develop poster that illustrates the various parts and components.

Research

- Students could research how operation of CNC machines is comparable to other automated machining processes. Specifically, a comparison between an assembly line and the CNC process could be compared. This could then be passed in as a written assignment

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

Topic 2: General CNC Machine Types and Applications

Outcomes

Students will be expected to

2.2.1 Identify an industrial application for CNC turning, CNC milling, CNC bending and CNC cutting [3.404]

2.2.2 Describe the general construction and capabilities of a CNC router machine [2.404]

Elaborations - Strategies for Teaching and Learning

Industrial application of

CNC turning - lathes are used to turn materials into a rounded surface such as metal parts for automobile and airplane industry

CNC milling – a machine tool used for shaping of metal and other materials. CNC mills can reproduce just about anything for industrial application., a good example would be parts used in the automobile sector.

CNC bending – Used where a part needs to be bent to a specific angle. Often used in automotive, furniture, aerospace and heating and ventilation industries.

CNC cutting – There are many CNC cutting systems, a lot will depend on the material that is being cut. Industry uses CNC lasers, water jet, routers, plasma and knife cutters to fabricate different products for society.

CNC routers are generally constructed with heavy duty steel bases, that have aluminum tables that allow material to be secured. The gantry is the part of the CNC router that moves along the x-axis and allows the router to essentially float over the cutting surface. The router will be attached to the gantry. The spindle is the part of the machine doing the cutting. Think of it as the actual router, such as a standard wood router. Each axis employs a linear drive system that moves the spindles in that axis. The CNC linear drive system includes a motor, a linear bearing system, and some sort of lead screw assembly. The lead screw assembly provides motion of the mechanical device. There are two types of motors found on CNC wood router machines, which are stepper motors and servo motors.

The uses of CNC routers are expanding in both the small and large woodworking shops. New applications for CNC machines are being created on a daily basis that range from furniture components to raised panel doors, moldings, hardwood flooring, paint brush and hammer handles, guitar bodies, gun stocks and much more.

Topic 2: General CNC Machine Types and Applications

Suggested Assessment and Evaluation Strategies

Paper and pencil

- Students could research and write a report on the industrial application for CNC turning, CNC milling, CNC bending and CNC cutting. Students should describe at least one application for each of the types of CNC machine types.

Presentation

- Students could create a table that illustrates how the various CNC machines are used in industry

Discussion / Research

- Class could brainstorm to discuss how each CNC machine could be used in industry. Ideas can be written on the board or poster paper and then students could use the internet to research their findings.

Paper and pencil

- Students could research and write a report that describes the general construction and capabilities of a CNC router machines. Students should research to discover illustrations that show different CNC routers,

Presentation

- Students could develop a presentation that describes the general construction and capabilities of a CNC router machine. Using images of CNC routers students could label the parts of the router.

Design Portfolio

- Students could put and overview of the material presented into their design portfolio.

Resources

Topic 2: General CNC Machine Types and Applications

Outcomes

Students will be expected to

- 2.2.3 Explain the basic operation of CNC machine controllers [2.404]

Elaborations - Strategies for Teaching and Learning

Machine Controllers take your machining instructions from your G-Code and converts the G-Code into motion. The controller interprets the signal pulses from your Control Computer and instructs the machine to move. The Machine Controller is made up of various electrical and electronic parts. Essentially this unit is the brains that converts instructions from a computer into movement and tool use on the CNC machine.

A CNC machine consists of motors for movement and, in our case a spindle for machining. The controller is the device that sends electrical pulses to the motors, be they servo or stepper, so that the CNC spindle will move on its correct path. There are usually three directional motors in simple CNC machines. One for the X-axis, one for the Y-axis and one for the Z-axis. The controller electrically activates the motors to move the CNC machine in whatever direction has been programmed in the G and M Codes. It also regulates the voltage and electricity to the proper levels for smooth operation of the motors. Different motors have different electrical requirements so the controller also has a transforming function.

The CNC Controller then has three main functions:

1. Interpretative - interprets signals from the computer into commands for the motors and spindles
2. Control - uses electrical impulses to convert the commands into actions through software and hardware
3. Transformation - converts input electrical source into required DC electrical impulses at the proper levels.

The CNC controllers in schools in Newfoundland and Labrador also have a fourth function in many cases; that of safety device. The kill switch found on these machines disables controller functions and removes the possibility of electrical impulses reaching the motors.

In the case of CNC in schools, the controller is commercial in nature, has been designed and implemented for the specific CNC machine in question. A quick search of the internet, using “CNC at home” as a search item will show that there are other ways of controlling CNC machines, and in fact that aspects of other technology education courses in the Newfoundland and Labrador curriculum will aid in the design and creation of such a controller.

Topic 2: General CNC Machine Types and Applications

Suggested Assessment and Evaluation Strategies

Paper and pencil

- Students could research and write a report that describes the basic operation of CNC machine controllers [2.404]

Practical

- Students can be taken into the fabrication area to demonstrate how the CNC controller functions when the CNC router is in operation.

Research/Presentation

- Students could research on the internet how CNC controller can be created. In the course of this research, emphasis on looking at the processes that take place in the controller should be specified. Students could then either formally present to the class or create a poster outlining the functions of the controller and how they can be replicated “at home”.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

Topic 3: CNC Programming, G & M Codes

Outcomes

Students will be expected to

- 2.3.1 Explain the relationship between CNC programs and CNC machine operation [2.404]

Elaborations - Strategies for Teaching and Learning

A CNC program is a set of instructions that are written on a computer and are interpreted by a CNC machine. They include the following elements:

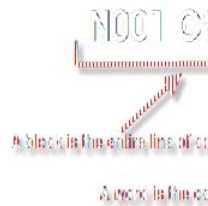
- Units (inches, mm)
- Coordinates (x,y,z)
- Positioning (absolute or incremental)
- Feed, speed and plunge rates
- Tool control (changing tools/bits)
- Types of actions required (movement of the tool)

Units

The CNC machine uses a digit to determine its length of travel. The units that correspond to the length of travel must be set in the software that runs the CNC machine. These units are set as either metric (mm) or Imperial (inches). The units of the design must match the units of the CNC machine. If you use mm on your design then you must use mm as the basic unit for the CNC machine. If two different units are used the machine will not cut the project properly.

Coordinates

CNC machines work in a Cartesian coordinate system. This is a numerical system that describes the location of an object by describing its distance from a fixed point along three linear axis referred to as X, Y, and Z. The path of the axis is shown below.



Positioning

When the coordinates on the project are relative to one fixed point then you are using an absolute position and when your coordinates are relative to the last coordinate they are incremental.

Topic 3: CNC Programming, G & M Codes

Suggested Assessment and Evaluation Strategies

Paper and pencil/ Presentation

- Students could create a flowchart outlining the processes and the material contained in a normal CNC program. In this chart they could also indicate the importance of the information contained in each section. This could be created in a poster for display in the class as a whole.

Discussion

- In small groups students could discuss what is contained in a CNC program and why each section is there. This should be done in the context of running a project on a CNC machine. These groups can be brought together into a full class for a debate on what is actually needed in their specific case.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Practical activity/Role play

- Students could act out each of the elements of a CNC program. Taking a drawing they could point out what each of their functions does for the CNC machine creating a part from the drawing. This could be done in small groups or as a whole class activity.

Resources

Topic 3: CNC Programming, G & M Codes

Outcomes

Students will be expected to

- 2.3.1 Explain the relationship between CNC programs and CNC machine operation [2.404]

Elaborations - Strategies for Teaching and Learning

Feed, Speed, and Plunge Rates

These are three variables that are controlled independent of the design. The type of material that is being machined typically determines the feed and speed rates of the router. The feed rate is the value of how much material is being removed from the stock in a given time frame and is calculated by using the following formula:

$$\text{Feed Rate (mm/min)} = \text{Tooth Load (mm)} \times \text{Number of Teeth} \times \text{Spindle Speed (rpm)}$$

The following table provides approximate tooth loads for common materials used in design and fabrication 2202.

Material	Flat End Mill	Ball Nose End Mill
Wood		
Bronze/Brass	0.17 mm	0.20 mm
Aluminum	0.27 mm	0.32 mm
Plastics	0.17 mm	0.22 mm

In order to calculate the feed rate, you need to know the speed of the spindle or router and this is also dependant on the diameter of the tool. As you can tell, there is a delicate relationship between speed and feed rates and their proper calculation requires the close observation of a number of factors.

The table below shows the speed rates for common materials used in Design and Fabrication 2202.

Material	Speed
Wood	500 meters/minute
Brass/Bronze	55 meters/minute
Aluminum	200 meters/minute
Plastics	250 meters/minute

A cutting tool must spin when travelling through the stock to allow for material removal. The speed rate refers to the spindle speed of the router and the speed with which the tool travels through the stock. Each cutter has its own speed and the speed rate is determined by the size of the cutting tool and the type of material being machined.

The plunge rate refers to the rate at which the bits plunges into the stock being machined.

Topic 3: CNC Programming, G & M Codes

Suggested Assessment and Evaluation Strategies

Resources

Topic 3: CNC Programming, G & M Codes

Outcomes

Students will be expected to

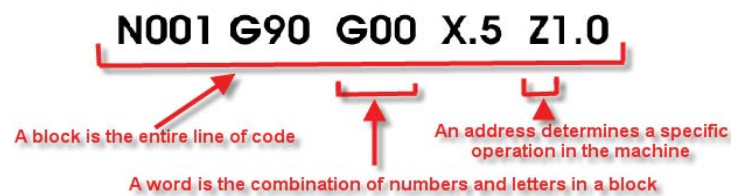
- 2.3.2 Differentiate between Blocks, Words, and Address characters used in CNC programs [2.404]

Elaborations - Strategies for Teaching and Learning

Teacher preparation

When looking at the NC code in a text editor there are several divisions of code types. These types are:

- Blocks: lines of code in the program.
- Words: each block contains a string of words. An NC word is a code that is made up of alphabetic character (address character) and a number.
- Address: a character that determines a specific event within the CNC machine.



Student Activity

The students in this case could take a number of nc coded programs and do a search of them to find structures of this type. In each case they could identify the blocks , words and address sections and elaborate what each one is doing in that section. This builds upon the last few outcomes and sort of brings it all together. It is not expected that at this point students will be able to write their own G&M codes but rather recognize what is going on.

This activity could begin as a teacher lead activity, viewing one section of a long nc program that has these structures in it. In a teacher lead discussion the class could discuss what is happening in each case and then through the use of one of the available simulation programs or from an online version, they can see if their surmise is correct,

Topic 3: CNC Programming, G & M Codes

Suggested Assessment and Evaluation Strategies

Practical activity

- Students could plot an entire nc coded program and try to predict what it is doing. They will do this by identifying the structures and then trying to estimate what is happening. This can be done in groups and then their educated guesses should be compared either to a simulation or by comparing to a finished product

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Research/Paper and pencil

- Students can do a short project on where else in technology these types of structures exist. Looking at some common programming languages is a good place to start. In the course of the research students should try and find why these structures are used or surmise why.

Resources

Topic 3: CNC Programming, G & M Codes

Outcomes

Students will be expected to

- 2.3.3 Differentiate between preparatory G codes and miscellaneous M codes used in CNC programs [2.404]

Elaborations - Strategies for Teaching and Learning

G codes and M codes are the basic types of functions that occur during machine operation. G codes are also known as preparatory codes. They tell the machine what type of movement should be performed. For example, rapid moves, linear feed moves, arc feed moves, thread cutting, etc.

M codes are also known as miscellaneous codes and they are used to control functions such as turning on and off the spindle, when a tool change should occur, and when the program ends. **They control the overall machine, causing it to stop, start, turn on coolant, etc., Other codes deal with the path of the cutting tools. Different machine tools may use the same code to perform different functions.**

G-codes are also called preparatory codes, and are any word in a CNC program that begins with the letter 'G'. Generally it is a code telling the machine tool what type of action to perform, such as:

- Rapid move
- Controlled feed move in a straight line or arc
- Series of controlled feed moves that would result in a hole being bored, a workpiece cut (routed) to a specific dimension, or a decorative profile shape added to the edge of a workpiece.
- Change a pallet
- Set tool information such as offset

There are other codes examples of which are found below

- X absolute position
- Y absolute position
- Z absolute position
- F feed rate
- S spindle speed
- N line number
- T Tool selection
- D Cutter diameter/radius offset
- H Tool length offset

Topic 3: CNC Programming, G & M Codes

Suggested Assessment and Evaluation Strategies

Research/Presentation

- Students could research the variety of codes available for use in nc. This could then lead to a class presentation explaining the use of common codes and some codes that are specific to other types of CNC use.

Discussion

- The origins of G and M codes could be discussed in class at this point. Students and teachers could engage in such a discussion to get a clearer understanding of why they were developed and why this type of code evolved.

Design Portfolio

- Students could place the results of their research and notes from the discussion into their design portfolio.

Resources

Topic 3: CNC Programming, G & M Codes

Outcomes

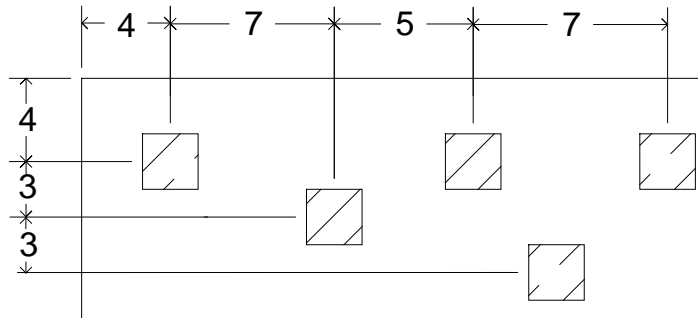
Students will be expected to

- 2.3.4 Differentiate between absolute and incremental coordinates [1.401]

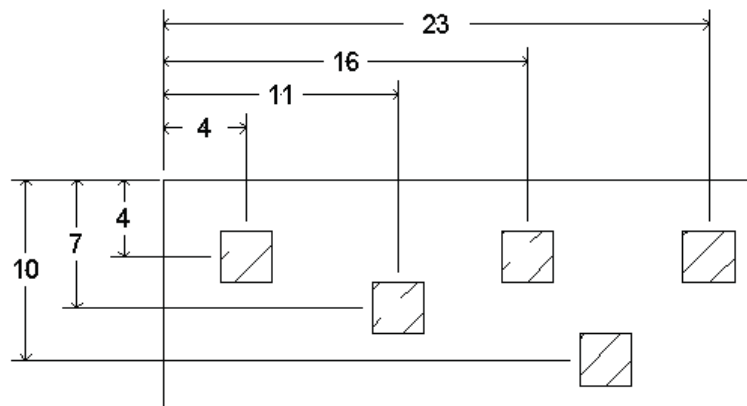
Elaborations - Strategies for Teaching and Learning

When looking at coordinates, the origin is the first thing to consider. Absolute increments are relative to the origin of the Cartesian axis (0, 0) and incremental coordinates are coordinates that are relative to the last known point.

This is an example of incremental positioning



This is an example of absolute positioning.



Students should be engaged in a discussion of how the two types of coordinates can be used in the CNC machining process. The direction of the discussion should encompass not only where such different coordinates should be used but also why.

Topic 3: CNC Programming, G & M Codes

Suggested Assessment and Evaluation Strategies

Presentation

- Students could produce either a large poster or a short presentation to the class on the differences between absolute and incremental coordinates.

Discussion

- Students could be engaged in a discussion concerning the terms absolute and incremental in more than just CNC. Within this discussion questions as to why it is important to differentiate between the two in manufacturing could be raised.

Design Portfolio

- Students could place the results of their research and notes from the discussion into their design portfolio.

Resources

Topic 4: Overview of the CAD/CAM/CNC Process

Outcomes

Students will be expected to

- 2.4.2 Identify opportunities for application of CNC programming in completion of the Design Project [1.401, 1.403]

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

An integral part of following the CAD/CAM process in the completion of the group Design Project will be the CNC manufacture of one of the basic required components. Through completion of UNIT 2.0, students should have an appreciation for the complexity of writing CNC programs for complex 3D shapes. Based on this basic knowledge of CNC programming, students should assess the Design Project manufacturing requirements with particular emphasis on identifying components that can and/or should be produced using CNC machining.

The teacher could lead the students in an interactive discussion focused on identifying the Design Project general manufacturing requirements before students, working in groups of 2 or 4, assess the potential for application of CNC. Following the student group activity, the teacher could summarize group findings and through interactive class discussion, note the degree of difficulty in CNC programming that may be associated with some components.

Suggested Student Activity

Following the initial class discussion, students in groups of 2 or 4 will assess the manufacturing requirements for the Design Project with a particular view to identifying opportunities to apply CNC machining in the manufacture of components.

Topic 4: Overview of the CAD/CAM/CNC Process

Suggested Assessment and Evaluation Strategies

Discussion

- This section lends itself to a discussion as students should reflect on what their project ideas entailed and how it can be done in the CNC environment. The small project at this point may start to be expanded into something larger, but at all times using CAD/CAM/CNC must be a consideration after this point.

Design Portfolio

- Students could put notes from their discussions and conclusions in their design portfolio.

Resources

Unit 3

Basic CNC Operations

Purpose

In this unit students progress from the basics of CNC programming to actual operation of a CNC machine. Using the CNC program for the simple shape written in the previous unit, students are given the opportunity to learn the basics of set-up and operation of the CNC machine. This unit will serve as the safety and preparatory section before machining takes place. Students will learn the fabrication lab safety rules and the construction and operation of CNC machines. UNIT 3 consists of the following sub-units:

Topic 1: Fabrication Room Safety (4 hours)

Topic 2: CNC Machine Safety Rules and Guidelines (2 hours)

Topic 3: CNC Machine Construction and Operation (2 hours)

Topic 4: Machining Basics (3 hours)

Profile

Unit 3 reinforces the CNC programming knowledge that students acquire in the previous unit. Through direct observation of the machining process, students are able to visually associate the coded instructions in their CNC program with machine motions and tool actions. Although actual machining will take place further along in the course, students will have a grasp of how it will be operating.

Implementation

Delivery of UNIT 3 will occur primarily in the fabrication lab. Following review of the safety rules and CNC machine construction and operation, the teacher should discuss the basics of machining, such as speeds, feeds, and clamping that machinists must consider in both manual and CNC machining applications. Direct supervision will be required when students operate the shop CNC machine.

Evaluation

Unit 3 consists of 11 hours of instruction which represents 10% of the total course teaching time.

Safety should be evaluated as an assessment for learning, and use of the CNC machine should not occur until students have successfully passed their evaluations.

Topic 1: Fabrication Room Safety

Outcomes

Students will be expected to

- 3.1.1 develop personal rules of conduct based on standard practice and revise at the end of this topic section.
[5.401, 5.402, 5.403]

Suggested Teaching and Learning Strategies

Occupational Health and Safety rules clearly state that employees and employers have rights and responsibilities. It is the responsibility of employers to provide a safe work environment, and the responsibility of employees to maintain that environment. Establishing a personal code of conduct will allow students to take ownership of their OH&S rights and responsibilities, and will also serve to establish the baseline for safety within the lab.

This outcome also involves the project management topic within Unit 3. One of the duties of the project manager in that section is to ensure that all students are working in a safe manner. It is important that this does not become a case of one student “telling” on another, but rather the students working together to keep the fabrication lab safe. It is suggested that if an unsafe practice is identified that the first step would be to talk to the worker in question, the second step would be to make an informal report, and the third step would be to put a “stop work” order on the project in question. This could easily become a whole class learning experience, addressing aspects of the fabrication lab safety section, the Occupational Health and Safety section and the project management section.

Activity

Students will create a contract concerning their behaviour in the fabrication lab. This contract will provide details of appropriate behaviour and consequences.

At this stage a parental permission form, signed and returned, would be advisable.

Topic 1: Fabrication Room Safety

Suggested Assessment and Evaluation Strategies

Although in most assessments the activities are suggested, in the case of the safety sections most are prescribed. Wording for these specific activities will be indicative.

Practical Activity

- Students are expected to create a contract concerning their behaviour in the fabrication lab. This contract will provide details of appropriate behaviour and consequences. In the development of the contract, students should include the prior learning from the previous section on Occupational Health and Safety.
- At this stage a parental permission form, signed and returned, would be advisable.

Resources

Topic 1: Fabrication Room Safety

Outcomes

Students will be expected to

- 3.1.2 identify common hazards within the construction work site (Fabrication Room). [5.402, 5.403]

Suggested Teaching and Learning Strategies

Safety rules within the fabrication lab should be clearly and prominently displayed. One of the first activities for students in this course or any of the other skilled trades and technology courses should be to design and implement a safety information program within the lab site. This will enable students to become aware of the common hazards in the fabrication lab, while taking personal responsibility for identification and awareness for others using the space.

This outcome ties in directly with the preceding topic on OH&S and specifically the SAFE work program. The first step in that program is:

- Spot the hazard.

The remainder of the SAFE work program involves

- Evaluate the risk
- Find a safer way
- Every Day

All students should walk through their fabrication space and identify the hazards.

As well students should be instructed in the proper procedures to be followed in the event of finding a hazard in the room. What steps should be followed and in what order. As a young worker there is one route, as a student there is another. Students should work in groups of two and if a hazard is spotted the instructor should be informed while one student stays onsite to identify the hazard for the others in the fabrication room.

An activity could also revolve around specifically setting up hazards in the fabrication lab that students have to identify. In the form of a role play this can be very effective.

Topic 1: Fabrication Room Safety

Suggested Assessment and Evaluation Strategies

Practical Activity

- Each group of students could be given a piece of equipment or situation that they can then address with rules, messaging, clear zones and floor plans. This is something that can be done in every course on a yearly basis, and it can also form the basis of a design project with the inclusion of OH&S and safe work principles.

Group Activity

- Students could audit the fabrication lab themselves for hazards. Each group could do an assessment of the space and then compare notes with the other groups.

Resources

Skilled Trades 1201 Curriculum Guide

Topic 1: Fabrication Room Safety

Outcomes

Students will be expected to

- 3.1.3 demonstrate safe practice for use of standard hand, portable power, and stationary power tools, for stock preparation. [5.402]

Delineation

Students should

- Complete the safety program for each tool that requires it, and that is intended for use;
- State and describe the safe operating procedure for using a tool at 100% accuracy; and
- Demonstrate safe use of a tool with 100% accuracy.

Suggested Teaching and Learning Strategies

Teacher Preparation

Although this course is based in CNC Fabrication, the use of power tools for stock preparation is a requirement. This outcome is included for completeness, and to ensure that students operate such tools safely. Safe and proper CNC operation will be covered in an outcome to follow.

For power tools in particular, ensuring students are properly certified to use them is essential. Normal practice is to use a combination of written and performance testing for each student for each tool. It is a good idea to maintain a chart of who is qualified for what tools. You may wish to provide class wide instruction on tools, followed by individual testing.

Include:

- Function of the tool:
- Parts of the tool:
- Adjustments that can be made and the correct procedure for completing them;
- Safe usage of the tool for performing the common tasks; and
- Procedures to follow in instances where the tool is not functioning or functioning outside the specs.

It is to be expected that not all students will qualify for all tools. It is also expected that students who qualify for different tools may wish to trade tasks.

Points to emphasize

- Safety is not just a set of rules. Safety is a way of life. It is a set of ideas, attitudes, behaviours and practices that are essential to the workplace. Safe practice does not eliminate risk, but it reduces risk. Safe practice is risk management.
- Safe use of tools is primarily using them in the prescribed manner, with the proper adjustments and usage procedures. It is also avoidance of clearly understood unsafe practices. In particular shortcuts and quick workarounds often increase risk.
- Only students who are qualified will be allowed to use a particular tool. It is not necessary for all students to use all tools. It is perfectly acceptable for a group to divide the tasks

Topic 1: Fabrication Room Safety

Suggested Assessment and Evaluation Strategies

Pencil and Paper

- Students are expected to complete a written safety test (passing grade is 100%) and complete a practical safety demonstration for each of the hand, portable power, and stationary power tools to be used in the fabrication laboratory. These tests are available in the teacher's resource guide.

Portfolio

- Students could report in their portfolio each tool they are qualified to use, and the date and time of the qualification. These should be checked or verified by the teacher in each case.

Resources

Skilled Trades 1201 Curriculum Guide

Skilled Trades and Technology Safety Guide, Tool Safety Test Appendix

Topic 1: Fabrication Room Safety

Outcomes

Students will be expected to

- 3.1.3 demonstrate safe practice for use of standard hand, portable power, and stationary power tools, for Design and Fabrication. [5.402]

Delineation

Students should

- Complete the safety program for each tool that requires it, and that is intended for use;
- State and describe the safe operating procedure for using a tool at 100% accuracy; and
- Demonstrate safe use of a tool with 100% accuracy.

- 3.1.4 demonstrate safe practices within the fabrication area, and proper procedure for handling shop emergencies. [5.402, 5.403]

Suggested Teaching and Learning Strategies

so that each member can qualify for a different group of tools.

- Tool qualification can occur on an as-needed basis.
- Tool qualification has no margin of error. Only 100% on written/verbal/performance tests are acceptable for qualification.
- Each tool is different but all tools have commonalities. Point out the commonalities with other tools when demonstrating a tool's function, adjustments and operating procedures.

The purpose of this outcome is to formalize the normal safety procedures established in classrooms and laboratories. Teachers should outline the various contingencies and the proper safe response by students. These should include but are not limited to:

- Fire extinguishers;
- Eye wash station;
- Fire exits;
- Emergency shut-off; and
- First aid kit.

This should be standard procedure for any classroom, and a fire drill during the year should be held with every class who will be using the fabrication room. **It should be noted that normally there are two exits from the fabrication room and a discussion of when it is appropriate to use each one should be undertaken.**

Topic 1: Fabrication Room Safety

Suggested Assessment and Evaluation Strategies

Resources

Practical Activity

- Students could participate in a mock emergency within the fabrication lab. This simulation should involve injury, fire, electrical situations and chemical spills.

Topic 1: Fabrication Room Safety

Outcomes

Students will be expected to

3.1.5 understand the importance of WHMIS and demonstrate knowledge of its key features. [5.402, 5.403]

3.1.6 recognize the need to consult Material Safety Data Sheets (MSDS) when dealing with chemicals on the jobsite. [5.402]

Suggested Teaching and Learning Strategies

WHMIS is an acronym for Workplace Hazardous Materials Information System. It involves a series of national regulations concerning the communication of information about the use and storage of hazardous material in the workplace. Science 1206 and the locally developed Workplace Safety 3220 both present a short course in WHMIS. In this course we will touch on the basics of the system and what has to be looked for in the fabrication lab.

Activity

Students should review the details of WHMIS, specifically:

- Supplier label;
- Workplace label;
- Material safety data sheets (MSDS); and
- Employee education.

The material safety data sheets are provided with all hazardous materials defined as those having the potential to cause a physical or health hazard.

The different classes of such material are:

- Class A - compressed gas;
- Class B - flammable and combustible material;
- Class C - oxidizing material;
- Class D - poisonous and infectious material;
- Class E - corrosive material; and
- Class F - dangerously reactive material.

This material has been presented in Science 1206 and Science 2200. Practical use of the knowledge is what is important in this course. Teachers should emphasize the importance of this information when dealing with safety in the Fabrication lab and on the jobsite for young workers.

Young workers disproportionately have the most accidents on the job, and some of this is due to a lack of knowing their rights and what information they should be looking for when working with chemicals

Topic 1: Fabrication Room Safety

Suggested Assessment and Evaluation Strategies

Paper and Pencil

- Students could review the details of WHMIS, specifically:
 - Supplier label;
 - Workplace label;
 - Material safety data sheets (MSDS); and
 - Employee education.

This should be done in a written quiz or report.

Role Play

- Students could role play a situation on the job for when an MSDS sheet is needed and should be supplied. A mock MSDS sheet can be used and in the role play discussions of what important information is contained within it could occur.

Research/Paper and Pencil

- Students could choose a common hazardous material in the Fabrication Lab and research the relevant Material Safety Data Sheet. A report to the instructor should be prepared on this material, its use and storage in the Fabrication Lab.

Presentation

- Students could present to the class on the importance of MSDS. In this presentation specific examples of where such a system may have saved a life or saved someone from an injury should be used

Portfolio

- Students could record in their portfolio the completion of the section on WHMIS.

Resources

Sample MSDS Sheet

Skilled Trades 1201 Curriculum Guide

Skilled Trades and Technology Safety Guide, Tool Safety Test Appendix

Topic 2: CNC Machine Safety Rules and Guidelines

Outcomes

Students will be expected to

- 3.2.1 Identify the safety features of the CNC machine (1.403, 2.401)

Suggested Teaching and Learning Strategies

Teacher Preparation

Hazards in the Fabrication Room are discussed at many times and at different levels within the Skilled Trades and Technology Program. As part of the familiarization process, students should be oriented to the CNC machine(s) that are present in their schools. This orientation should encompass the hazards accompanying CNC as well as the devices used for safe operation.

The CNC machine structure itself is the first and most obvious safety feature in that the device is surrounded by an enclosure. The enclosure fulfills two aspects of safety. One is the aspect of flying debris. Machinery operating at high rpms, such as the CNC router, need some way to protect the user from flying debris from cutting or catastrophic bit failure. The enclosure fills that role. The second aspect of safety that the enclosure is involved in is dust control and collection. The CNC machine can produce a significant amount of dust and encapsulating and concentrating it so that it can be collected is another important role of the enclosure. Beyond the specific structure of the CNC machine, there are other many and varied ways of keeping operators safe.

In some ways, the safety features on the CNC machine will be familiar for those who have used large power tools. The main common feature is the emergency stop procedure. Students should be made aware of the positioning of the emergency stop button. A demonstration of its use and the result of pressing it should be part of the familiarization process.

Students should also be made aware of locking mechanisms and machine interlock switches that may also be present on their CNC machine. Interlock guards are used such that when a machine is in operation the door is unable to be opened, conversely if the door is opened the machine will not operate. A locking mechanism is similar to the interlock, but in this instance the machine will not operate without a physical key present in the machine and turned.

Topic 2: CNC Machine Safety Rules and Guidelines

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could sketch, either by hand or using one of the available drawing programs, a diagram of the CNC machine present in their school. This sketch could include itemization of the various safety features included.

Research/Presentation

- Students could prepare a presentation for their classmates that will orient them to the CNC machine and its safety features. This presentation could also include research into other CNC machines and how their safety devices are comparable to the ones used in their school machine's case.

Research

- Students could research a variety of CNC machines in use in the industry and the methods they use for safety. These methods and features could be compared to the ones available on their school's CNC machine.

Portfolio

- Students could record in their portfolio the features outlined in this section.

Resources

Topic 2: CNC Machine Safety Rules and Guidelines

Outcomes

Students will be expected to

3.2.2 Demonstrate the safe operating procedure for CNC machine use. (2.401)

Suggested Teaching and Learning Strategies

The last level of safety features is the training that students have to receive before they can use the equipment. Students should qualify for use of this equipment by passing a series of written and practical tests. These practical tests involve observing teacher demonstrations and then demonstrating proper use of the machine for the instructor. Once the practical test has been completed then the written safety test would follow. This is an assessment for learning piece and students are expected to complete these tests at 100% accuracy before being permitted to use the CNC machine as an operator. It is understood that for the most part few students will operate the CNC machine without direct supervision by the instructor, but such training is still required for completeness.

Safe operation of a CNC machine is all about preparation. As part of that preparation, teachers and students must ensure that:

- Students are properly attired in their personal protective equipment (PPE)
- Enclosures are in place and are used in a safe manner
- Work on the CNC machine is properly supervised
- Cutters are correct for the material to be used and the job to be undertaken
- Cutters are in good repair and are not bent or dull
- Safety switches are in good operating order
- Software controls are in place during tool change and stock/jig setup
- Workpiece is safely and securely clamped
- Students remain with the CNC machine for the entire time of its operation on their project
- If a safety interlock switch is part of the CNC machine to be used, that switch should be tested to ensure it is in good working order.

As in any job to be done in the Fabrication room, students should think through the process from start to finish. Hurrying a project so that an allotted time on the router can be used is not a safe practice. Safety is something that has to be planned in advance, carried out with attention to detail and never compromised.

Topic 2: CNC Machine Safety Rules and Guidelines

Suggested Assessment and Evaluation Strategies

Pencil and Paper

- Students are expected to complete a written safety test (passing grade is 100%) and complete a practical safety demonstration for the CNC machine to be used in the fabrication laboratory. These tests are available in the Skilled Trades and Technology Safety Guide Appendix.

Portfolio

- Students could report in their portfolio the date and time of the qualification. These should be checked or verified by the teacher in each case.

Demonstration

- Students could demonstrate the proper, safe operating procedure for the CNC machine in question. This could be done for the class as a whole, and as part of the evaluation portion of the safety test.

Paper and pencil

- Students could develop a set of safety rules for the CNC machine they have been working on as a poster. After checking with the instructor, these rules could be posted in a area of the fabrication lab dealing with hand tools.

Resources

Topic 3: CNC Machine Construction and Operation

Outcomes

Students will be expected to

- 3.3.1 Identify the main components of the available CNC machine [2.404]

Suggested Teaching and Learning Strategies

Teacher Preparation

The cnc router most often used will be a three axis router, those being x, y, and z. There are several components of these routers that students must be familiar with. These include:

- Router bed: these typically are equipped with an aluminum bed with a t-slot table for relatively easy clamping of stock. These can also be fitted with a wooden sacrifice surface .
- Gantry: the gantry is essential the arm that travels from front to back along the router bed. The router or spindle is attached to the gantry with the ability to travel up and down vertically (z-travel), and the ability to travel left and right along the gantry (x-travel). The gantry itself travels from front to back along the router bed which gives it the y-travel capability.
- Axis limit switches: these are switches that “limit” the travel of the gantry and the router. They prevent the gantry from travelling too far on the y axis and also prevent the router from travelling too far on the x and z axis.
- Tool calibration touch pad: this is available on some models of cnc routers. This touch pad allows the user to set the z zero at the top of the stock. I makes zeroing the stock on the z axis much quicker and more accurate.
- Controller: this box houses much of the electronics that allow the cnc router to be “controlled” with a computer and a piece of software. It generally has a “keyed” function as well as an on/off switch.
- Emergency shut off: available on some routers this remote shut-off allows the user the capability to shut down the router if they see an impending problem. It is meant to serve as a fail safe to avoid problems.
- Router enclosure: these are usually constructed of carbonite and serve the purpose of enclosing the router to prevent injury in the event of catastrophic bit failure. They also serve to contain the dust and particulate generated during the routing process. Some have interlock switches that prevent the router from operating while the enclosure door is a-jar.
- Router: generally a basic router affixed to the gantry, it operates like any other router. It has the manual ability to turn on and off as well as a manual switch for varying the spindle speed. These generally come with 6, 9, and 12mm interchangeable chucks (1/4”, 3/8”, 1/2”) to allow for bits with varying shank diameters. They require the operator to manually change the router bits as needed.

Topic 3: CNC Machine Construction and Operation

Suggested Assessment and Evaluation Strategies

Portfolio

- Students could record in their portfolio all of the main components of their school's CNC machine.

Research/Presentation

- Students could research a variety of CNC machine types and compare their major components with the ones outlined for their school's machine.
- Students could also research CNC lathes and identify parts that have the same function but different names and manifestations.

Paper and pencil

- Using the diagram students drew in a previous outcome, students could label their diagram of the CNC machine. This labelled diagram could be displayed in the fabrication lab.

Practical activity

- Students could take a digital photo of the CNC machine in their school, and with the aid of photo editing software put labels on the different parts of the machine. This could be done as part of the development of a fill-in test for other students to take.

Resources

Topic 4: Machining Basics

Outcomes

Students will be expected to

- 3.4.1 Identify the common tools used for turning and milling [2.404]

Suggested Teaching and Learning Strategies

Teacher Preparation

Tools used for turning and milling are not about the tool, but about what the tool does. Cutting is the main task of any milling or turning tool, and the tool used is based on a variety of factors:

- Material type : This will determine the type of bit to be used (high speed steel, carbide, etc) and the feed rate and spindle speeds.
- Profile of the cut: Depending on the desired effect, different bits will produce a variety of finishes.
- Amount of material to be removed : If it is necessary to remove a large amount of material then a larger diameter bit will generally be used. Finer detail will require smaller aspect bits for detail work.

There are several types of bits that are commonly used in CNC routers. These include but are not limited to:

- End mills (flat) : Generally used for doing contour cuts or for pocketing out sections. They come in a variety of sizes and with a varying number of flutes but generally 2 and 4.
- Ball nose : Used for surface contouring.
- Chamfer : 45 degree chamfer bit used for v-grooving and some engraving.
- Engraving : 60 degree engraving or lettering bit used for creating text or fine lines.

When using endmills to rout out pockets or to do through cuts on contours then the following rule of thumb applied: Safe depth of cut is generally limited to one half the diameter of the cutter for each pass.

Turning Tools:

In some instances there may be a CNC Lathe in the fabrication lab. In this case two of the common tools available are the Finish Right 35 degree and the Rough Right 80 degree. These are generally used for rough clearance of the stock and for finishing the stock. Different materials allow for variations in depth of cut and the user should be careful not to exceed the safe depth of cut for these tools.

Topic 4: Machining Basics

Suggested Assessment and Evaluation Strategies

Research/Paper and pencil

- Students could draw small representations of the cutters used in their classroom. The representations should have a full description of the cutter, its primary uses and distinctive features. This could be done as a research assignment, presentation or poster for display in the fabrication lab.

Research/Presentation

- Students could research a variety of cutters and their specific uses in the industry. These cutters should be described in detail with images where applicable and possible.
- Students could research different turning tools, commenting on how they are same and different from their brethren used in routing. This could be done as an assignment or a presentation.
- Students could research router bits in general, focussing on those bits that do not have applicability to the CNC world.

Resources

Topic 4: Machining Basics

Outcomes

Students will be expected to

3.4.2 Overview jig and fixture requirements for machining [2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

Proper clamping of material is an important step in the CNC process. Zeroing axis is a moot point if the stock to be cut is not held in place. There are a number of ways this can be done, and in the Fabrication world there are different reasons for using them. Two of the more common types are jigs and fixtures.

A jig is used for repeatability, such that if you want to create the same piece over and over again. In unit 4 you will discuss repeatability as an important reason for use of CNC in the first place. Jigs are also called templates or guides which then would guide the tool along the path as previously defined.

A fixture, as the name may suggest, fix objects in place. They are used to hold objects in place and clamp them to the operating surface of the machine. This allows the programming to operate from a known and fixed point.

Another viable option for holding the work piece is the use of a sacrificial bed. This involves attaching a wooden material to the router bed. This allows the user to physically attach the work piece to the sacrificial bed using fasteners. It would be useful for the user to completely machine the sacrificial wood surface before using to ensure a “true” surface. This sacrificial bed would need to be replaced on a regular basis to ensure accuracy and safety.

Within this course, the use of jigs and fixtures can take on a variety of faces. The two most likely scenarios though are that there is a purpose built jig or that a commercial product is procured. Students will internalize this material better if they have a hand in the creation of the jig or fixture to be used. Considerable detail will have to be part of this exercise so that no safety hazards are created,

Topic 4: Machining Basics

Suggested Assessment and Evaluation Strategies

Research/Presentation

- Students could research a variety of jigs and fixtures used in industry when milling or routing. The specific usage, applicability, cost and complexity should form the basis of their research. A written assignment or presentation can be completed at this point.

Practical Activity

- Students could design a jig or fixture for use with the school's CNC machine and/or a specific project that is undertaken by several groups. If the design meets with the approval of the teacher and the other groups, creating the jig or fixture could be an extension activity.
- Students could design and implement a sacrificial bed for their school's CNC router. This bed design should take into account material type, size (depth) and ease of replacement. A discussion of why such a bed is used would be a useful addition here.

Resources

Unit 4

Three-Dimensional Computer Aided Design

Purpose

Computer Aided Design or CAD has had a variety of meanings since its inception. Originally called computer aided drafting, it was so named because it replaced the physical act of drafting. It allowed the drafter to be more productive and accurate in producing and modifying technical drawings. That name has evolved away from its drafting routes because of what is encompassed in the software. The newest generation of CAD software, due to the power of some of the tools being used, has almost made the software irrelevant allowing students to concentrate on the design more thoroughly.

In industry the CAD system is sometimes linked to a CAM or computer aided manufacturing software system. This combination makes for a complete system from design drawings to actual manufacture of the product. This increases efficiency and gives industry the ability to respond quickly to product changes. It also allows industry to perform low volume and custom production that would otherwise not be cost effective. Operators of these combined systems have to be proficient in both engineering drawing production and manufacturing methods.

This unit introduces students to the basic drawing, modify, and display tools available in conventional 3D CAD software. Students are also given the opportunity to observe the CAD/CAM process including CAD file export, CAM file generation, CNC machine set-up and part production through a teacher demonstration. Several topics are addressed in this unit including:

- Topic 1: Creating Entities (4 hours)
- Topic 2: Display Manipulation (2 hours)
- Topic 3: Modifying Entities (2 hours)
- Topic 4: Dimensioning (3 hours)
- Topic 5: Plotting (1 hour)
- Topic 6: Computer Aided Manufacture (2 hours)

Profile

Students will use CAD software to make a simple detail drawing on the computer. They will then dimension the drawing and plot a hardcopy. The drawing for a simple project will then be transferred to CAM software for eventual part production on a computer numerical control (CNC) machine.

Implementation

This unit allows the student to progress from a design drawing through to a built prototype. Students develop basic skills in CAD and CAM that are later further developed during completion of the design project in Unit 5. An introduction to the draw, modify and display tools used in conventional CAD software to create engineering drawings is first provided. This is followed by an introduction to CAM which overviews the procedure needed to transfer CAD files to CAM software for eventual production on a Computer Numerical Control (CNC) machine.

Evaluation

Unit 5 consists of 16 hours of instruction which represents approximately 14% of the total course teaching time.

Topic 1: Creating Entities

Outcomes

Students will be expected to

- 4.1.1 Identify the key areas of the CAD interface (1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

The CAD operator has to be familiar with the CAD interface before learning the methods to create and modify drawings. The teacher should provide students with an overview of the CAD interface including the drawing area, menu areas, status areas, and so on. Key identifiers and related terminology should be introduced at this stage. The optional methods available to execute commands should also be reviewed including the mouse, keyboard, and menus.

The teacher will identify for students the various areas of the CAD interface and introduce key terminology that will be used throughout the unit. These should include but are not limited to:

- Model display window
- Contextual menu items
- Feature Manager Design Tree
- Property Manager
- Configuration Manager
- Solid Works Resources Window
- Design Library Window
- Tool box
- File Explorer

Some of the terms used in this area are:

- Axis
- Plane
- Origin
- Face
- Edge
- Vertex

Students should orient themselves to the Solid Works interfaces by working through a self-directed tutorial. The Solid Works teacher guide has a series of tutorials for students. As well Solid Works the program has an interactive tutorial within it. It is suggested to start that students work through the interactive tutorial found in Solid Works and then work through the teacher guide tutorials.

Topic 1: Creating Entities

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could work through the first series of tutorials within Solid Works. These could be either the interactive tutorials or the self-directed tutorials.

Presentation

- Students could do a short presentation to the class on one aspect of Solid Works for the class. In this manner students could become more familiar with the interface.

Research

- Students could compare and contrast the various CAD software and how they differ from 3 D modelling software.

Paper and pencil

- Students could do a quick overview of the tutorials and create a short guide to Solid Works for new users. This guide could be in print or web format, and should include steps and hints to use these more specifically.

Resources

Design and Fabrication 1202
Teacher's Resource Guide

Solid Works - CAD Software

Solid Works Teacher Resource
Guide, Unit 1

Topic 1: Creating Entities

Outcomes

Students will be expected to

- 4.1.2 Create basic 2D entities
(1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

In CAD, technical drawings are generally developed by drawing and modifying a number of basic elements or entities including lines, circles, arcs, and points. The drafter's first requirement in order to use CAD is the ability to accurately create these basic entities.

Solid Works is more than a CAD program, although it has CAD elements. Solid Works is design automation software that creates 3D solids. The solids or models are made up of parts, assemblies and drawings. Using the interface students begin the process by creating the base feature.

Points to emphasize:

- The base feature is a two dimensional drawing that will inevitably become the 3D model. It is the first part of the drawing.
- A boss feature adds material to the part and is also created from a 2D drawing.
- A cut feature removes material from a part and is created from a 2D drawing.

In all of these cases the 3 dimensional rendering is created from a 2D entity. Students must be aware of this if they are to be successful in this topic.

The teacher must demonstrate to the student how to create these basic entities using the keyboard, mouse and menus. Each student could then complete a tutorial that overviews the CAD tools used to create basic entities and then develop the CAD drawing for a simple project assigned by the teacher or of the design project introduced in previous units.

Topic 1: Creating Entities

Suggested Assessment and Evaluation Strategies

Research

- Students could research a variety of 3 dimensional CAD products and how they handle the base feature.
- Students could compare and contrast 2 dimensional CAD programs with 3 dimensional CAD products. In this comparison important features such as ease of use, compatibility with systems and cost should be factors.

Presentation

- Students could do a quick demonstration of how each of these features occur from a 2 dimensional drawing. In this demonstration each of the three features should be included.

Tutorial

- Students should complete the first set of tutorials assigned by the teacher. This is considered a mastery section and simple completion should be sufficient for mark.

Practical Activity

- Students should take the drawing they completed in the last unit and develop a 2 dimensional feature from it.

Resources

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1

Topic 1: Creating Entities

Outcomes

Students will be expected to

- 4.1.2 Create basic 2D entities
(1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

In CAD, technical drawings are generally developed by drawing and modifying a number of basic elements or entities including lines, circles, arcs, and points. The drafter's first requirement in order to use CAD is the ability to accurately create these basic entities.

Solid Works is more than a CAD program, although it has CAD elements. Solid Works is design automation software that creates 3D solids. The solids or models are made up of parts, assemblies and drawings. Using the interface students begin the process by creating the base feature.

Points to emphasize:

- The base feature is a two dimensional drawing that will inevitably become the 3D model. It is the first part of the drawing.
- A boss feature adds material to the part and is also created from a 2D drawing.
- A cut feature removes material from a part and is created from a 2D drawing.

In all of these cases the 3 dimensional rendering is created from a 2D entity. Students must be aware of this if they are to be successful in this topic.

The teacher must demonstrate to the student how to create these basic entities using the keyboard, mouse and menus. Each student could then complete a tutorial that overviews the CAD tools used to create basic entities and then develop the CAD drawing for a simple project assigned by the teacher or of the design project introduced in previous units.

Topic 1: Creating Entities

Suggested Assessment and Evaluation Strategies

Research

- Students could research a variety of 3 dimensional CAD products and how they handle the base feature.
- Students could compare and contrast 2 dimensional CAD programs with 3 dimensional CAD products. In this comparison important features such as ease of use, compatibility with systems and cost should be factors.

Presentation

- Students could do a quick demonstration of how each of these features occur from a 2 dimensional drawing. In this demonstration each of the three features should be included.

Tutorial

- Students should complete the first set of tutorials assigned by the teacher. This is considered a mastery section and simple completion should be sufficient for mark.

Practical Activity

- Students should take the drawing they completed in the last unit and develop a 2 dimensional feature from it.

Resources

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1

Topic 1: Creating Entities

Outcomes

Students will be expected to

- 4.1.2 Create basic 2D entities
(1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

In CAD, technical drawings are generally developed by drawing and modifying a number of basic elements or entities including lines, circles, arcs, and points. The drafter's first requirement in order to use CAD is the ability to accurately create these basic entities.

Solid Works is more than a CAD program, although it has CAD elements. Solid Works is design automation software that creates 3D solids. The solids or models are made up of parts, assemblies and drawings. Using the interface students begin the process by creating the base feature.

Points to emphasize:

- The base feature is a two dimensional drawing that will inevitably become the 3D model. It is the first part of the drawing.
- A boss feature adds material to the part and is also created from a 2D drawing.
- A cut feature removes material form a part and is created from a 2D drawing.

In all of these cases the 3 dimensional rendering is created from a 2D entity. Students must be aware of this if they are to be successful in this topic.

The teacher must demonstrate to the student how to create these basic entities using the keyboard, mouse and menus. Each student could then complete a tutorial that overviews the CAD tools used to create basic entities and then develop the CAD drawing for a simple project assigned by the teacher or of the design project introduced in previous units.

Topic 1: Creating Entities

Suggested Assessment and Evaluation Strategies

Research

- Students could research a variety of 3 dimensional CAD products and how they handle the base feature.
- Students could compare and contrast 2 dimensional CAD programs with 3 dimensional CAD products. In this comparison important features such as ease of use, compatibility with systems and cost should be factors.

Presentation

- Students could do a quick demonstration of how each of these features occur from a 2 dimensional drawing. In this demonstration each of the three features should be included.

Tutorial

- Students should complete the first set of tutorials assigned by the teacher. This is considered a mastery section and simple completion should be sufficient for mark.

Practical Activity

- Students should take the drawing they completed in the last unit and develop a 2 dimensional feature from it.

Resources

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1

Topic 1: Creating Entities

Outcomes

Students will be expected to

- 4.1.3 Use file management tools for CAD drawings. (1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

When drawings are created in industry they have to be stored, cataloged and retrieved to make changes and copies. The same applies to drawings that are generated using CAD. The student needs to know the importance of keeping control of the original drawing, filing of drawings for easy access, and the retrieval of drawings to make modifications and copies.

The teacher must go through the filing systems of the CAD software to demonstrate how to store a drawing and make a backup. The file management must also include how to create folders and sub folders. The use of the various storage media will also need to be discussed.

Within Solid Works there is a powerful file and folder search option. Files can be found and recovered even if haphazardly saved. This does take time though, and to more parsimoniously use their time, students should set up a distinct folder and sub-folder system.

All Solid Works files save in a particular format. For example:

- Parts save as *.sldprt
- Assemblies save as *.sldasm
- Drawings save as *.slddrw

These are the extensions found at the end of the file and introduce a new concept for students, each of these extensions has more than three letters. You can also see the commonalities of the files in question. Each extension starts with the three letters sld (solid) and then three letters logically mated to the file type they are representing (prt for part, asm for assembly, drw for a drawing)

Students could complete a self-directed tutorial on file management using Windows Explorer. They will then be required to set up the necessary folders for their design project.

Topic 1: Creating Entities

Suggested Assessment and Evaluation Strategies

Tutorial

- Students should complete the set of tutorials dealing with searches and folder creation assigned by the teacher. This is considered a mastery section and simple completion should be sufficient for mark.

Practical Activity

- Students could create a series of folders to be used in the remainder of this course. The folders should have a logical structure, and be placed in an easy to find location. A students network drive would be best.

Research Assignment

- Students could compare and contrast the way Windows Explorer and Solid Works Explorer find, store and report files. This could be done in a tabular form.

Resources

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1

Topic 2: Display Manipulation

Outcomes

Students will be expected to

- 4.2.1 Use display tools to manipulate viewpoint of a drawing. (1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

During and following the creation of entities, the display of the entities may need to be modified. Display manipulation in CAD involves using one of a number of commands that control the size and position of the entities displayed on the monitor. For example, an entity can be displayed at an enlarged or reduced scale by using one of several ZOOM commands.

Solid Works has a series of commands dealing with views. Automatically arranging objects or parts into:

- Isometric views,
- Wire frame,
- Oblique,
- Oblique shaded and a variety of others.

Students should experiment with all of these views and demonstrate their usefulness. The teacher should demonstrate to the students how the display size and position of entities can be changed using the drawing previously developed by the students in topic 1.

The entire view menu, which is contextual, should be reviewed in this section. Students should get a feel for how they are used, what they are and how to find them. They should also examine how in some instances views cannot be changed and why.

Suggested Student Activity

Each student will complete a self-directed tutorial that overviews the display manipulation tools available in the CAD software.

Topic 2: Display Manipulation

Suggested Assessment and Evaluation Strategies

Tutorial

- Students should complete the set of tutorials dealing with views, and how the menus are contextual. This is considered a mastery section and simple completion should be sufficient for mark.

Research/Presentation/Discussion

- Students could research a variety of other CAD programs and through demonstration versions of those programs examine how they handle views of models and parts. Either a class presentation or discussion of how this is done in other programs could be undertaken.

Practical Activity

- Students could create a part or use an existing part and take it through the variety of views available in Solid Works. Demonstration of this mastery for the teacher would fulfill this section of the unit. This could also be linked to outcomes from the previous unit dealing with detail and assembly drawings.

Resources

Design and Fabrication 1202

Teacher's Resource Guide

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1

Topic 3: Modifying Entities

Outcomes

Students will be expected to

- 4.3.1 Edit existing entities using available modify tools. (1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

During the construction of a drawing, entities have to be edited or modified. CAD software provides several commands that allow for efficient and quick editing. This is one of the advantages of using CAD.

Within Solid Works the 2 D entity created to start a 3 D model or part, is the basis for the remainder of the design process within this program. A solid entity is created from the 2 D sketch and significant modification is fairly difficult. The base feature would have to be changed and that would require to a certain extent a restart of the whole process. Simple things such as dimensions can be modified at any time. The Smart Dimension command will allow for this to occur at any time whether in sketch or 2 dimensions, or 3 dimensions. This is one of the major differences between Solid Works and other 2 D CAD programs.

Using the Modify menu command and other methods the teacher could demonstrate how the student can edit an entity created in CAD. Teachers could also demonstrate the use of the Smart Dimension command within Solid Works. The various uses for this command should be explored in some detail.

Suggested Student Activity

Students will individually complete a self-directed tutorial that overviews the commonly used modify tools in CAD. They will then be required to apply some of the modify commands learned in the completion of a simple 2D drawing exercise.

Topic 3: Modifying Entities

Suggested Assessment and Evaluation Strategies

Tutorial

- Students should complete the set of tutorials dealing with this topic. This is considered a mastery section and simple completion should be sufficient for mark.

Research/Presentation/Discussion

- Students could research a variety of other CAD programs and through demonstration versions of those programs examine how they handle views of entities and modifications. Either a class presentation or discussion of how this is done in other programs could be undertaken.

Practical Activity

- Students could create a part or use an existing part and take it through the steps necessary to make modifications in Solid Works. Demonstration of this mastery for the teacher would fulfill this section of the unit. This could also be linked to outcomes from the previous unit dealing with detail and assembly drawings.

Resources

Design and Fabrication 1202

Teacher's Resource Guide

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1

Topic 4: Dimensioning

Outcomes

Students will be expected to

- 4.4.1 Place dimensions on CAD drawings (1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

While the drawing views provide the “picture” of the part, the addition of dimensions permits its fabrication. As with manual drawing, the dimensions provide the size and feature location information that fabricators need to make the part. Typical CAD software allows the user to customize the dimensioning features and to place a wide variety of linear and radial type dimensions consistent with good engineering practice.

As discussed in the previous outcome dimensions are one of those aspects that can be changed at almost any time within Solid Works. The Smart Dimension tool will allow dimensions to be modified or added at any time within the design process. A variety of dimensioning options are open to the designer within this program. The various styles and options will be discussed in the next section

The teacher will demonstrate the style and placement of dimensions by taking a simple 2D CAD drawing and dimensioning it for the students. Teachers could also demonstrate the use of the Smart Dimension command within Solid Works. The various uses for this command should be explored in some detail.

Suggested Student Activity

Students will individually complete a self-directed tutorial that overviews the commonly used dimension tools in CAD. Each student will then place dimensions on the simple 2D CAD drawing that was developed in topic 1.

Topic 4: Dimensioning

Suggested Assessment and Evaluation Strategies

Tutorial

- Students should complete the set of tutorials dealing with Smart Dimensioning both for 2 D and 3 D objects. This is considered a mastery section and simple completion should be sufficient for mark.

Research/Presentation/Discussion

- Students could research a variety of other CAD programs and through demonstration versions of those programs examine how they handle dimensions. Either a class presentation or discussion of how this is done in other programs could be undertaken.

Practical Activity

- Students could create a part or use an existing part and take it through the steps necessary to add and modify dimensions in Solid Works. Demonstration of this mastery for the teacher would fulfill this section of the unit. This could also be linked to outcomes from the previous unit dealing with detail and assembly drawings.

Practical Activity Extension

- Students could Smart Dimension a variety of 2 D shapes within Solid Works. A running log of how this is accomplished should be added to the students portfolio.

Resources

Design and Fabrication 1202

Teacher's Resource Guide

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1-3

Topic 4: Dimensioning

Outcomes

Students will be expected to

- 4.4.2 Create basic dimension styles (1.403, 1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

In different technical areas the drafter will use different styles to show the dimensions and notes on a drawing. Styles can also vary for specific applications and industries. The thrust of this activity is to give the student an introduction to dimension styles and how to create them.

Within Solid Works there are a number of style that can be affected within the smart dimension tool:

- Tolerance/precision,
- Dimension text,
- Witness/leader display,
- Primary value,
- Display options, and
- Break lines.

Each of these could be reviewed by students and an overview of what each can do should be done by the teacher prior to use. The interactive help function, help guides, tutorials and other tools within Solid Works will help with this instruction. The best way to try them out though is to use them, whether in a real situation or a mock one. Students will become more familiar and more comfortable with their use if they have used them in many different way and many different times.

The teacher will review the main dimension style tools and demonstrate how a dimension style can be created.

Suggested Student Activity

Students will individually complete a self-directed tutorial that overviews dimension style tools in CAD. Each student will then create a dimension style for the simple 2D CAD drawing that was developed in topic 1.

Topic 4: Dimensioning

Suggested Assessment and Evaluation Strategies

Tutorial

- Students should complete the set of tutorials dealing with dimensions styles. The online tutorial is more appropriate for this topic. This is considered a mastery section and simple completion should be sufficient for mark.

Research/Presentation/Discussion

- Students could research a variety of other CAD programs and through demonstration versions of those programs examine how they handle dimensions styles and changing of styles. Either a class presentation or discussion of how this is done in other programs could be undertaken.

Practical Activity

- Students could create a part or use an existing part and take it through the steps necessary to change dimension styles in Solid Works. Demonstration of this mastery for the teacher would fulfill this section of the unit.

Resources

Design and Fabrication 1202

Teacher's Resource Guide

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1-3

Topic 5: Plotting

Outcomes

Students will be expected to

4.5.1 Develop basic page setups for plotting. (1.405)

4.5.2 Plot a 2D CAD drawing. (1.405)

Suggested Teaching and Learning Strategies

Teacher Preparation

Although a CAD drawing is stored electronically, a hardcopy or plot is still required for reference on-site. Production personnel use the plot or blueprint in the shop during fabrication, while the original file remains under the control of the drawing office. Plotting a drawing requires consideration of the plot scale, the sheet size, and the plotting device. One of the first steps in the plotting process involves setting up the page or specifying the sheet size, plot scale, and printer type. This page setup helps ensure consistent high quality plots.

The instructor will demonstrate page set-up for an A4 size plot on the available printer.

Suggested Student Activity

Students will individually complete a self-directed tutorial that overviews plotting in CAD. Each student will then plot the simple 2D CAD drawing that was developed in topic 1 using a page set-up for an A3 size plot.

Teacher Preparation

Although a CAD drawing is stored electronically, a hardcopy or plot is still required for reference on-site. Production personnel use the plot or blueprint in the shop during fabrication, while the original file remains under the control of the drawing office. Plotting a drawing requires consideration of the plot scale, the sheet size, and the plotting device. One of the first steps in the plotting process involves setting up the page or specifying the sheet size, plot scale, and printer type. This page setup helps ensure consistent high quality plots.

The instructor will demonstrate page set-up for an A4 size plot on the available printer.

Suggested Student Activity

Students will individually complete a self-directed tutorial that overviews plotting in CAD. Each student will then plot the simple 2D CAD drawing that was developed in topic 1 using a page set-up for an A3 size plot.

Topic 5: Plotting

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could practice using a variety of print set-up options to prepare their drawing for print. These should be previewed to check for appropriateness for the task at hand

Research/Discussion

- Students could research how difficult it is to set up for printing in other CAD programs.

Tutorial

- Students could complete the tutorial on Drawings and printing from the Solid Works online tutorial.

Practical Activity/Portfolio

- Students could print their drawing for placement in their portfolio and review by the instructor. These should be previewed before printing to save paper.

Research/Discussion

- Students could research how difficult it is to print in other CAD programs.

Tutorial

- Students could complete the tutorial on printing from the Solid Works online tutorial.

Resources

Design and Fabrication 1202

Teacher's Resource Guide

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1-4

Printer or Plotter capable of processing A3 size paper

Design and Fabrication 1202

Teacher's Resource Guide

Solid Works - CAD Software

Solid Works Teacher Resource Guide, Unit 1

Printer or Plotter capable of processing A3 size paper

Topic 6: Introduction to Computer Aided Manufacture (CAM)

Outcomes

Students will be expected to

- 4.6.1 Identify the elements of the CAD/CAM/CNC process. [1.403]

Suggested Teaching and Learning Strategies

Teacher Preparation

The elements of CAD/CAM/CNC are what make the process work. Each of the stages uses software that is most appropriate to the work at hand and may be accomplished by specifically trained individuals. The first step is the design, which may start out as a sketch as we discussed early in Unit 4. From this a rendering in a CAD program is made. This drawing is much more precise than the sketch and includes all of the information necessary to produce the product as a whole.

The CAD drawing completes the first element of the process. The next step is CAM. CAM stands for Computer Aided Manufacturing, and involves a specific program to aid in this endeavour. The CAM package plots the tool paths, defines the tools and basically lays out what will happen on the CNC machine. It usually does this in a graphical form, and may include elements of design in its programming. The CAM package plots how the tools will move, what they will do and how they will do it. It does all that and also converts the end product into what is called G&M code.

G and M code is the language of the CNC machine. G-codes are the codes that position the tool and do the actual work, M-codes manage the machine and T codes are tool-related codes. This is the language the machine talks in.

We have now moved onto the CNC element of the process. The G and M code is transferred to the CNC machine, and the program is ready to run. There are some steps for preparation though. Even though the CAM program has set the tool paths and decided how things will run from there, it does so from a specific zero point. The CNC machine must be “zeroed” to that point before the program can run and the product created. As well the stock must be placed in the proper location and prepared to take the tool. Finally in some CNC machines (such as ours) the proper tool must be placed in the collet. Once that is finished the process is complete and the product is ready to run.

Three elements creating a single process and product.

Topic 6: Introduction to Computer Aided Manufacture (CAM)

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could prepare a drawing that could be transferred to a CAM program. This drawing must be in a format that is accepted by the CAM software.

Research/Presentation

- Students could research the origins of G and M codes and why they are used in CNC machines. A short presentation to the class or a poster for display could be developed with the information found.
- Students could also research the origin of CNC machining as a whole and discuss the possible reasons it was invented. Comparisons between the CNC available today and in the past should be made.

Portfolio

- Students could put the relevant information about G and M codes and CAM software into their portfolios.

Resources

Solid Works - CAD Software

Master CAM - CAM Software

Topic 6: Introduction to Computer Aided Manufacture (CAM)

Outcomes

Students will be expected to

- 4.6.2 Identify various CAM packages that are available for use. [1.403, 1.405, 2.402, 2.403]

Suggested Teaching and Learning Strategies

Teacher Preparation

As discussed in a previous outcome, CAM software translates CAD drawings into code readable by CNC machines. CAM programs can be generic, such that they can be used for many different tasks, or industry specific, such that they can only be used with a set tool choice, a set material choice and a number of other limiting parameters. In either case,

Examples of generic CAM used in schools include but are not limited to:

- Master CAM
- Feature CAM
- Star CAM

These are basic, generic CAM packages that allow a number of CNC machines, tools and materials to be used. They are useful for their adaptability and ease of use.

A variety of other softwares are available, some as demoware and some as freeware. These can be found online. Finding one of these CAM packages, installing it and working with it would be a good student activity in this section.

As well, CAM programs can be industry specific. Guest speakers and a visit to a local business that used CAM and CNC would be a worthwhile activity.

Topic 6: Introduction to Computer Aided Manufacture (CAM)

Suggested Assessment and Evaluation Strategies

Research/Discussion/Presentation

- Students could research the variety of CAM softwares available for use and the specific use each could have in industry. A discussion or presentation to the class could occur at this point.

Research/Internet

- Students could do a search of CAM software online, finding freeware that is available in this area. A quick view of the software in question and a report on its usefulness could be placed in the students portfolio.

Practical Activity

- Students could, using one of the demo or freeware programs, complete a conversion from Solid Works to CAM. They should run through a rudimentary tool path.

Research/Presentation

- Students could research an industry that uses CAM, and the specific CAM they use. They could then make a presentation on the industry and the CAM it uses along with the reasons why a specific type was created.

Resources

Solid Works - CAD Software

Master CAM - CAM Software

Unit 5

Computer Aided Manufacturing

Purpose

While CAM software is generally capable of both 3D model geometry creation and CNC program development, it is typically used for the latter with the 3D model geometry being imported from 3D CAD design software as discussed in UNIT 4.0. This unit focuses on use of CAM software in the development of CNC programs through completion of the following sub-units:

- 5.1 Overview of CAM Software and Features
- 5.2 CAD File Import and Defining Tools
- 5.3 Defining Toolpaths
- 5.4 Post-Processing
- 5.5 CNC Machine set-up and Production
- 5.6 Design Project CNC Production

Profile

This unit is intended to familiarize students with the capabilities of CAM software, particularly in relation to CNC program development, not to develop their proficiency in its use. Students use the software tools for defining tools, tool lengths, stock size, feeds, and speeds and learn the sequence to post-process and transfer the CNC program to the CNC machine controller. Finally, the students complete the production of the part using the Shop CNC machine.

Implementation

In this unit, a series of self-directed computer lab tutorials and related computer lab exercises are used to introduce students to the basic functions of the CAM software used to develop CNC programs. Students are given the opportunity to apply the skills learned, through completion of these exercises, to the group Design Project.

Evaluation

Unit 5 consists of 20 hours of instruction which represents 18% of the total course teaching time.

This is a significant learning section, as the skills learned here will be integral in the following units. Assessment of this section should reflect the importance of this material, and should be based in skilled building exercises and practical activities.

Topic 1: Overview of CAM Software and Features

Outcomes

Students will be expected to

- 5.1.1 Identify the main areas of the CAM software user interface [2.404]

Suggested Teaching and Learning Strategies

Teacher Preparation

CAM software includes command tools for the creation of 3D model geometry, specification of the machining parameters such as tool paths, and the generation of a CNC program for operation of a CNC machine. The teacher should demonstrate the key capabilities of the CAM software, specifically the following:

- Menu Bars: Main buttons such as file, edit, view, etc
- Tool Bars: Graphics views, planes, trim/break, utilities, etc.
- Operations Manager: This houses the toolpath manager, solids manager, and art manager. It can be used to generate, sort, edit, regenerate, verify, backplot, and post any operation with a view to enabling students to identify the common command tools available

An example of a student activity would be:

Students will create a rectangular shape using the “Create” menu. This menu allows for the creation of various shapes and features. Students would then be expected to create another rectangle inside the first but this time they would use the Parallel Line feature and the Edit, Trim features to create the rectangle. This emphasizes the geometry creation and the editing features of the software. Students would then be expected to save the drawing they created. Other points to emphasize would be the “Operations Manager” and its importance when it is time to select the machine time and set up the stock for cutting. For more in depth uses students could be expected to create other shapes and incorporate several of the different shapes into a single drawing. Practice will ensure students get a good comfort level with the software.

Topic 1: Overview of CAM Software and Features

Suggested Assessment and Evaluation Strategies

Tutorial

- Students can work through the MasterCam tutorials that are provided. These are self-directed tutorials.

Presentation

- Students could be expected to choose various aspects of the MasterCam software and do presentations on those particular aspects. For example a group of students may be asked to do a presentation on the Creation tools.....Line, Rectangle, Arc, etc.

Assignment

- Students could be expected to take entities that have been previously created and edit them. This could make them familiar with the editing features of MasterCam.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 2: CAD File Import and Defining Tools

Outcomes

Students will be expected to

- 5.2.1 Import the 3D CAD geometry for a simple 3D part from SolidWorks. [2.401]

Suggested Teaching and Learning Strategies**Teacher Preparation**

As previously noted, CAM software is often used exclusively for specifying machining parameters and generating a CNC program based on the geometry of the part to be machined that has been created using 2D or 3D CAD software.

The teacher should demonstrate application of the commands used for CAD file import from SolidWorks. Points to be emphasized would be ensuring the 3D Model is created on a front view, the model has been extruded, and that the geometry created is fairly simple and straight forward. More complex geometry will be created as the students skills improve.

Following the teacher demonstration of the software capabilities, each student could completes a self-directed tutorial that requires them to import the CAD geometry for one of the simple 3D components developed in sub-unit 5.5

While completing the tutorial students should ensure that the following steps are completed.

- Create a 2D shape, extrude it to a 3D shape and save it to a specific location using Solid Works.
- Use the MasterCam Add-In for SolidWorks to move the 3D model from SolidWorks to MasterCam.
- Check the 3D shape in MasterCam to ensure the transfer went smoothly....check for correct size and shape.
- Students then save the geometry in MasterCam to create a .mcx file for later use.

Topic 2: CAD File Import and Defining Tools

Suggested Assessment and Evaluation Strategies

Presentation/Practical Activity

- Students could be expected to create a basic 3D part in SolidWorks and import it into MasterCam. They could be asked to do presentations to the class outlining the steps to be taken

Tutorial

- Students could be expected to complete the basic tutorial on how to import 3D objects from SolidWorks to MasterCam. This can be done with a variety of 3D objects and students could be expected to check their objects after they have been imported.

Assignment

- Students can create their own tutorials on bringing 3D shapes into MasterCam.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 2: CAD File Import and Defining Tools

Outcomes

Students will be expected to

5.2.2 Follow proper procedures for setting up a piece of stock for the 3D shape created in 5.2.1 [2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

Stock creation and setup is a very important aspect of preparing a 3D shape for machining. The type of material being used for a particular job is important and needs to be specific to the shape being machined. Various materials are more suited to some jobs than others. The density, color, grain configuration, and other features all influence the finished product. For example some 3D shapes lend themselves better to hardwoods as opposed to softwoods.

Creating the piece of stock properly is very important. Knowledge of the X, Y, Z axis is important in choosing the proper piece of stock for the job. Knowing your stock size and properties is essential for proper use of the verification tool and for safe operation of the CNC machine.

Proper stock type is very important at this point. For example, using softwood for the creation of a crib board would create issues such as tear-out, etc. A piece of hardwood would be much more suitable and would produce a better finished product.

Suggested Student Activity

Students will do a comparison chart that shows the properties of various wood and light aluminum materials and their strong and weak points when being machined.

Topic 2: CAD File Import and Defining Tools

Suggested Assessment and Evaluation Strategies

Paper and Pencil

- Students could be asked to create a paper checklist of the proper sequence of steps to follow when setting up a piece of stock to be machined.

Presentation

- Students could be expected to do presentations on the various materials available to be machines and the benefits of choosing the proper one. For example, the benefits of using oak as opposed to pine for certain applications.

Assignment

- Students could be expected to do a paper assessment on the proper setup procedure.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 2: CAD File Import and Defining Tools

Outcomes

Students will be expected to

- 5.2.3 Define the various tools used in machining basic 3D shapes [2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

Tool definition is a very important aspect of machining. Various bits have different properties and are designed for cutting different materials. The teacher must stress that each tool is designed for a specific purpose and it must be used for the purpose it was intended for. The bits commonly used are the 3, 6, 13, 19, and 25 mm flat endmills, ball nose endmills, 6mm Chamfer (v-bits), and a 60 degree engraving bit. The flat endmills are used for pocketing and doing through cutting, the ball nose bits for contouring and the v-bits and engraving bits for doing finer work such as engraving and fine detailing

Students could be given various router bits and will be expected to do sample cuts on various materials. Based on the cuts and technical data on the bits, students can see the benefits of using a particular shape bit for a particular job.

These experimentations can be done in MasterCam using the verify tool and students can see how each bit reacts during different types of cutting. They can also do sample cuts in actual material.

Using the crib board as a sample project the capabilities of the various bits can be emphasized. For example the 3mm flat endmill can be used for drilling the peg holes. The size of this bit is essential for producing a good end product. Use of a bigger 6mm endmill for the through cutting on the contour shows the need for a larger, more robust, bit for doing heavier cutting. Finally, the use of a 45 or 60 degree engraving bit allows for engraving of text or fine lines to accent the final project. Knowledge of these bits is essential for application for good machining.

Topic 2: CAD File Import and Defining Tools

Suggested Assessment and Evaluation Strategies

Research/Presentation

- Students could be asked to do a research project on the various types of tools available for machining and then present their findings to the class.

Demonstration

- Students could be asked to do a practical demonstration for the class on the proper application for each type of bit. An example would be students demonstrating the proper use of the ¼” router bit to do through cutting.

Presentation

- Students could be asked to do a display of the various types of bits and the cuts they produce. This can serve as a good model when selecting bits for various operations.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 3: Defining Toolpaths

Outcomes

Students will be expected to

- 5.3.1 Identify the importance of selecting the proper feeds and speeds when cutting various materials[2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

While CAM software and CNC machines permit the production of complex 3D shapes that would be impossible to produce manually, the basic tenants of machining must still be adhered to. The type of material used, for example, is an important consideration since it directly affects the speeds and feeds required for precision machining. The teacher should review the basic machining rules governing determination of feeds, speeds, and the selection of the appropriate cutting tools. Chipload is simply defined as the thickness of a chip which is formed during the machining of a material. Chipload is critical because if the chip is the proper size, the chip will carry away the heat promoting long tool life. If the chip is too small, the heat is transferred to the cutting tool causing prematurely dulling. Too high of a chipload will cause an unsatisfactory edge finish, or part movement

The formula to calculate chipload is: $\text{Feedrate} / (\text{RPM} \times \# \text{ of flutes})$

To increase your chipload you can:

- Increase the feedrate
- Decrease the RPM
- Use less flutes

To decrease your chipload you can:

- Decrease the feedrate
- Increase the RPM
- Use more flute

The teacher should discuss with students how references such as the Machinery's Handbook are available to assist with this task. The teacher can do also demonstrations on various materials during the same job but varying the speeds and feeds. Students can then do a comparison of the chip created and the finished product.

Topic 3: Defining Toolpaths

Suggested Assessment and Evaluation Strategies

Research/Presentation

- Students could be asked to do research projects on speeds and feeds. They could be expected to discuss the proper speeds and feeds when using the various materials and cutters. They can then present their findings to the groups.

Presentation

- Students can do visual displays on the chips created using the same materials and different feeds and speeds. These visual displays could clearly show the differences and they can accentuate the proper speeds and feeds and the chips created when they are used properly.

Research

- Students could research what would happen if improper feed rates are used when cutting some materials. This could be handed in or presented to the class.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 3: Defining Toolpaths

Outcomes

Students will be expected to

5.3.2 Define toolpaths as it relates to the 3D model created in 6.2.1[2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

Following this review of machining basics, the teacher should demonstrate, using the geometry of a simple 3D part to illustrate, the options available for defining toolpaths or the motion the tool will follow in cutting the part from the stock. The teacher should stress the fact that the previous section on feeds and speeds is critical to generating the proper tool path. The different tool paths such as pocket, contour, drill, surface rough, and so on are all tool paths that are suited for specific purposes. Students must be able to decide which tool path is needed and the importance of choosing the correct tool path.

Students could compare two toolpaths assigned by the teacher (e.g. Pocket and contour).

These two toolpaths would be used in the creation of a basic door sign or in the creation of a simple jewel case. The contour toolpath is created using an endmill or straight router bit. It is primarily used for through cutting or profiling a shape. Depth of cut is important here as the general rule of thumb is acceptable depth per pass is one half the diameter of the bit. So a 6mm bit would only cut 3mm deep on each pass.

The pocket toolpath is generally used for just that, creating a pocket of any shape. A smaller diameter bit will allow for sharper corners but also means more passes to complete the pocket. The size of the bit used will be dictated by the size of the pocket needed.

Topic 3: Defining Toolpaths

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could be given a variety of shapes and be asked to select and create the proper toolpath. Each group could then be asked to present to the class their toolpath selection and the justification for choosing that particular toolpath. Other groups can then make suggestions about other options and then choose the optimum toolpath for the job.

Assignment

- Students could be asked to calculate the proper depth of cut using various bits. This can be done on pencil and paper and then a display board can be created for the various bits included for the schools bit collection.

Practical Activity/Presentation

- Students could be asked to create models using various shapes and various toolpaths for display in the shop.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 3: Defining Toolpaths

Outcomes

Students will be expected to

5.3.3 Verify various toolpaths using machining simulation in the CAM software [2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

The teacher should demonstrate how the integrity of the CNC program that is generated based on the defined toolpaths can be checked using a graphical simulation of the machining process or what is typically referred to as machining verification. The CAM software allows the students to view a three-dimensional representation of the toolpaths that have been created. The importance of the verification tool is that it allows the student to see if the tool-paths look correct and to assess any problems they see. The teacher needs to stress the value of toolpath verification. The simulation saves on materials and tools by allowing students an opportunity to see the mistakes before they actually happen. The simulation is a MUST before students create nc code to take to the CNC machine.

Students could take a basic 3D object, create a basic toolpath such as a pocket or a contour, and then verify the toolpath using the simulation feature of the CAM software. Students must assess the toolpath and determine the validity of the toolpath and assess any errors or omissions. Things to be aware of during this activity are:

- Depth of cut is appropriate for the bit being used
- Tabs are used and appropriately placed during a through-cutting procedure.
- Stock setup has been completed correctly and the stock is the right size and type.
- Cutting direction and tool compensation is correct.
- Students should be required to modify the toolpath and observe the differences during the simulation.

Topic 3: Defining Toolpaths

Suggested Assessment and Evaluation Strategies

Tutorial

- Students could be expected to complete tutorials on toolpath creation and simulation.

Assignment

- Students can create self directed tutorials on toolpath creation. These can then be exchanged and tested with the other groups, edits suggested, and tutorials then modified and finalized.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 4: Post-Processing

Outcomes

Students will be expected to

- 5.4.1 Generate NC code, display and post-process NC part file for machining of a simple 3D part using the CAM software[2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

After the CNC program has been graphically verified, the CNC program can be viewed for editing. The teacher should demonstrate the command tools required for this (MasterCam X Editor), identify some of the common G and M codes that appear in the CNC program, and relate this to the basics of CNC programming covered in UNIT 3.0. The complexity of the CNC program generated using CAM should be compared to the basic program developed manually in UNIT 3.0 with a view to illustrating the advantage of using CAM to develop more complex CNC programs. The teacher should stress the following:

- XYZ extents
- Proper tool numbers
- Proper z increments
- Proper feeds and speeds

Emphasis needs to be placed on the importance of verifying that the G-codes match what was intended when the toolpaths were created. This is another fail safe that allows students another opportunity to ensure that all toolpaths are correct and that proper procedures were followed before they actually machine the part.

The teacher should also define and discuss the need for post-processing of the CNC program as a means of converting the universal CNC coded instructions initially generated by the CAM software to the particular form required by the shop CNC machine controller.

Student Activity

After students have generated their G-Code students will be expected to do a search through the code to determine the xyz extents, the z increments, the tool path orientation in relation to the origin, the tool numbers and proper tool changes, and the feeds and speeds for the various tools.

Topic 4: Post-Processing

Suggested Assessment and Evaluation Strategies

Assignment

- Students could be given printouts of the G-code for a project. They could be asked to identify the xyz extents, the tools used and the tool numbers, the speed and feed rates, and any other applicable criteria. These should be then verified to ensure they are accurate.

Practical Activity

- Students could be expected to complete self-directed tutorials on the creation of nc code.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 5: CNC Machine set-up and Production

Outcomes

Students will be expected to

- 5.5.1 Set-up stock in shop CNC machine for production of a simple 3D part [2.401]

Suggested Teaching and Learning Strategies

Teacher Preparation

After the CNC program has been generated, verified and post-processed, the simple 3D part created in sub-unit 5.5 should be produced using the shop CNC machine. This will give students another opportunity to set-up stock in the machine, establish the stock reference axes, establish the tool references, and operate the machine to produce the part. Stress must be placed on the following

- Stock is properly clamped to the table - This can be achieved using a clamping system or by attaching the stock to a sacrifice piece using fasteners.
- Zeroing the X and Y axis - This is generally the bottom left hand corner of the stock but it may vary depending on the project.
- Orienting the stock in the proper direction - Basically this refers to cutting in the X or Y direction but it will also be influenced by the grain of the stock.
- Ensuring the bit is properly inserted into the chuck - This would mean snugging the bit into the chuck but not over tightening the chuck.
- Zeroing the Z axis so the tool is properly oriented to the surface of the stock - This involves using the touch pad on some routers but on others it involves the accepted practice of zeroing the bit to the surface using a piece of paper
- Ensuring the spindle is turned on and working properly - Always check the spindle/router manually to ensure it is working properly before running your program.

The students should also be shown the features on the CNC machine software that allow them to verify the integrity of their G-code.

This should be a student driven exercise that is directly monitored by the teacher to ensure safety and to provide direction as required.

This entire process is generally completed with the class as a group but again with each student or group as they set up their first project to be cut.

Topic 5: CNC Machine set-up and Production

Suggested Assessment and Evaluation Strategies

Paper and pencil

- Students could be expected to create a checklist of steps to complete in the proper set-up of stock to be machined. This list could be compiled into a chart to be put on display near the CNC machine.

Safety/Practical Activity

- Students will be expected to do a safety test on the proper setup procedure for setting up stock in the CNC machine.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Topic 6: Design Project CNC Production

Outcomes

Students will be expected to

5.6.1 Use the CAM software to develop the CNC program required for production of one of the components for the Design Project.

Suggested Teaching and Learning Strategies

Teacher Preparation

Student knowledge of CAM software and operation of the shop CNC machine is applied to the Design Project in this sub-unit. In groups of 2, students could develop the CNC program, complete set-up routines, and operate the shop CNC machine to produce one of the components for the Design Project. Some of the suggested projects can include crib boards, door signs, or other activities. This project would encompass all the steps completed previously in this unit. Students could:

- Create the 3D shape in Solidworks,
- Export the shape to MasterCam,
- Choose the proper machine type,
- Set up the stock, create the toolpaths (contour, pocket, etc),
- Verify their toolpaths,
- Create the g-code (.nc file),
- Take their .nc file to the CNC machine for machining,
- Physically set up their stock,
- Zero the X, Y, and Z axis,
- Verify their g-code and
- Cut their project.

Taken as a whole this is a step-by-step process that students will follow every time they design something to be produced on the CNC machine. It is a good road map for them and for the instructor to ensure that nothing is missed.

Topic 6: Design Project CNC Production

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could be expected to generate a project to fabricate from start to finish, from the creation in the CAD software to the creation of the G-code that needs to be taken to the CNC machine.

Design Portfolio

- Students could put an overview of the material presented into their design portfolio.

Resources

- Master CAM - CAM Software
- Master CAM Software Tutorials

Unit 6

The Design Project

Purpose

The purpose of this unit is to allow the students to apply the knowledge and skills that they have acquired in the first five units through the completion of a group design project. The students will simulate the process actually followed in the field from the initial design concept through to development of the physical prototype. This unit will also develop the students' proficiency in the use of CAD/CAM through the completion of a set of working drawings and enhance their hands-on skills through the operation of CNC equipment during the production and testing of the physical prototype. Unit 6 includes seven main topics as follows:

- **Topic 1:** The Design Portfolio (1 hour)
- **Topic 2:** Defining the Problem (1 hour)
- **Topic 3:** Generating Options (2 hours)
- **Topic 4:** Selecting the Best Option (1 hour)
- **Topic 5:** Developing the Solution (8 hours)
- **Topic 6:** Prototyping and Testing (10 hours)
- **Topic 7:** Evaluation and Redesign (1 hour)

Profile

The product development cycle from the design concept to the physical prototype takes a variety of specialized skills and individuals working as a team. This unit will build on some of the previous group activities that students have done in the course but will give them more exposure to group dynamics as they work together to complete the project. Projects rarely go as smoothly as desired and students will have to learn how to deal with the stresses and frustrations brought on by group decision making and impending deadlines.

The design project will allow the students to fully experience the design process and they will be required to apply both their academic skills through completion of a design portfolio and their shop skills through the building of a physical prototype. The interrelation between design and fabrication is reinforced through this project as students learn by doing that both activities are mutually dependent.

Implementation

Unit 6 represents a synthesis of the first five units. Each topic in this unit corresponds to the main steps in the design process. Topics 1 to 4 focus on the generation of alternative design solutions and the selection of the best option for further development. Topics 5, 6 and 7 focus on development, testing, and refinement of the preferred solution in the form of a physical prototype. Ideally, the second term of the course would be dedicated to completion of Unit 6. The teacher can, however, adjust the project scope accordingly if coverage of Units 1-5 extends beyond the recommended durations.

The design projects should be selected by each group of students from one of several possible projects suggested by the teacher. This will help the teacher to ensure that projects are of reasonable scope and capable of being produced with the available CNC resources and within the available timeframe.

Due to the nature of design projects, the teacher will be expected to play the role of facilitator. The teacher will be expected to offer intermittent classroom instruction, formally and informally consult with student groups, and generally manage project activities to ensure that students work within time, budget and physical resource constraints. Students will be expected to supplement class/lab instruction with self-directed study, as each design project will present unique challenges.

Evaluation

Unit 6 consists of 24 hours of instruction and represents approximately 22% of the total course delivery time.

Unit Overview cont'd

Suggested Timeline

The timeline noted below is a guideline for the teacher.

Topic 1: The Design Portfolio (1 hour)

- SCO 6.1.1

Topic 2: Defining the Problem (1 hour)

- SCO 6.2.1
- SCO 6.2.2
- SCO 6.2.3

Topic 3: Generating Options (2 hours)

- SCO 6.3.1

Topic 4: Selecting the best option (1 hour)

- SCO 6.4.1
- SCO 6.4.2

Topic 5: Developing the Solution (8 hours)

- SCO 6.5.1
- SCO 6.5.2

Topic 6: Prototyping and Testing (10 hours)

- SCO 6.6.1
- SCO 6.6.2

Topic 7: Evaluation and Redesign (1 hour)

- SCO 6.7.1
- SCO 6.7.2
- SCO 6.7.3
- SCO 6.7.4

Topic 1: The Design Portfolio

Outcomes

Students will be expected to

- 6.1.1 List the requirements of the design portfolio (1.405)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

The design of a product and the associated activities such as research, meetings, evaluations and so on are ongoing activities and the design team has to keep records. The teacher should explain that students will be required to complete a design portfolio as they progress through the project.

As stated in the *Atlantic Canada Foundation document on Technology Education*, the design portfolio is essentially a diary of the project progress and contains all relevant information, especially trial and error information. It is used to illustrate the thinking and planning processes that students engage in while developing a technological solution to a problem. Assessment of this process is often indirect, in that the evidence comes from a variety of sources. The value of the portfolio depends on how well it represents this process.

As a first step in developing the design portfolio, the student groups will be required to write a design brief. As stated in the *Atlantic Canada Foundation document on Technology Education*, the design brief is negotiated between student and teacher and sets the conditions under which the student engages in a design activity. While design professionals are assessed mainly on the solution to the problem, students are assessed mainly on growth in their design capability.

Suggested Student Activity

In groups of 2 or 4, students should prepare the outline for a design portfolio. This outline should contain the design brief, title of the project selected, client (teacher's name), project location, and members of the design team (student group). As the students progress through the unit, their portfolios will be updated as directed by the teacher.

Topic 1: The Design Portfolio

Suggested Assessment and Evaluation Strategies

Portfolio

- Students could begin their design portfolio at this time. This is a separate portfolio from the digital portfolio the students have putting their work into up to this point.
- Students could develop their project ideas at this point. Although the problem statement occurs next, some idea of what the project will entail should be a part of developing the problem statement

Group Work

- Students will work in small groups to develop the design brief. This will include meetings as a group, interviews with the teacher and is expected to be an ongoing process.

Research Assignment/Presentation

- Students could research the origins and evolution of the design process. This could entail a written assignment, a presentation to the class or a timeline poster to be displayed.

Paper and pencil

- Students could create a graphic to represent the design process. This could be done as a flow-chart to accurately depict the various stages and paths such a process will take.

Resources

Atlantic Canada Foundation document on Technology Education

Topic 2: Defining the Problem

Outcomes

Students will be expected to

6.2.1 Develop a problem statement (1.401)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

The development of a problem statement is the initial and probably most important part of the design process. The problem statement focuses the team and delineates the broad parameters of the design process. Any design project is the result of a perceived need for a product. That need may relate to the requirement to upgrade or improve an existing product or system, or to fulfill a consumer requirement for a new system or product.

The teacher should define the need for a product and then work with the class to define the problem statement. For example the teacher could pose a problem involving finding specific classrooms in the building. Not all buildings are numbered distinctly or logically, and a numbering schema would be important, As well, creating signs that would have braille or be visually distinctive for the room they are identifying would be possible.

As an activity, the teacher could also have students work to define a perceived need. In industry tools such as polls and customer surveys are used as a means to identify new products. In a school sense the students could poll their peers, put out a questionnaire to staff and students or hold focus groups to find out what the school feels is a need. It should be noted that this should be a fairly restrictive process offering a choice of things that students are able to accomplish within the fabrication lab using the CNC machine and software. An example of this would be to develop signage for doors in the school.

If this is to be a major design project involving the whole class then the scope of what will be done should reflect this. If on the other hand the design project will involve a series of groups then the scope can be significantly reduced.

Suggested Student Activity

The student groups will develop a problem statement for their chosen design project.

Topic 2: Defining the Problem

Suggested Assessment and Evaluation Strategies

Practical Activity

- In groups students could develop a problem statement as the first step towards developing a product in this design process.

Portfolio

- Students could put the research and background material they used to develop their problem statement in their design portfolio.

Discussion

- Students could develop a questionnaire or focus group to discuss with their peers and teachers some things that could be produced to make things better in their school. The results of such a discussion could form the basis of the problem statement.

Research/Presentation

- Students could research other problem-solving approaches (such as the scientific method) and their similarities to the design process. A poster comparing and contrasting these methods could be placed in the Design and Fabrication labs.

Resources

Topic 2: Defining the Problem

Outcomes

Students will be expected to

6.2.2 Develop design objectives and related criteria. (1.401, 5.401, 5.402, 5.403)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Following the development of a problem statement the design team has to develop a set of measurable objectives that the design must meet. For each objective or design goal, corresponding criteria must be assigned that quantify or qualify the degree to which the objective must be met. For example, the objective “The room numbers must be displayed prominently” could have the associated criteria “Can be seen from a distance of 15 feet”.

The teacher should emphasize the need for measurable criteria where possible. In some cases, quantifying an objective in this manner is not possible and the criteria may be a qualifier. For example, the objective “The room numbering design must be aesthetically pleasing” could have the associated criteria “Must be approved by a review panel comprised of teachers and administration”. The teacher should also point out to the students that objectives are not static and may change as the project progresses.

For the more practical in school projects, the measurable criteria should be determined by the stakeholders, the students and teachers. So if the project is to be room numbering then there are certain logical things that have to be accomplished. It has to be sturdy enough to remain on a door opening and closing, large enough to be easily seen by people walking in the hallways and so on. The stakeholders in this instance may also look for it to blend into the decor of the building, be artistic etc.

Suggested Student Activity

The student groups will review a sample listing of objectives/criteria for the door numbering example and then develop the objectives and criteria for their chosen design project. These should be recorded in the design portfolio.

Topic 2: Defining the Problem

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could develop measurable criteria whereby their products can be measure against. This could be done in a large group or small group setting, but should have some teacher input.

Discussion/Presentation

- Students could present their measurable criteria to the class as a whole and take input from group discussions. This will help to refine the criteria and make the process more effective.

Research/Presentation

- Students could research a product development and outline the steps concerning the measurable criteria. This research would involve online searching and maybe some industry contact.

Portfolio

- Students could put the research and background material they used to develop their measurable criteria in their design portfolio.

Resources

Topic 2: Defining the Problem

Outcomes

Students will be expected to

6.2.3 Identify design constraints
(1.401)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Most design projects have constraints that limit the solution options available to the design team. Constraints are generally classified as physical, cost or time constraints. An example of a physical constraint relating to the door numbering design, for example, would be that the number must fit on and not impede the opening of a conventional 36" door. A cost constraint could be that the numbering must not cost more than \$10 per door. A time constraint could be that the design project must be completed within 3 months.

These design constraints will have a significant impact on what is finally produced, especially if the project is one suggested by staff and students.

- **Costs:** this will have to be negotiated with the teacher and perhaps the administration. A ballpark figure would be what a commercially made product would cost.
- **Size:** the final product must be able to fit out the door of the fabrication lab or fit out in pieces. This is a significant design constraint for many things created in this space.
- **Time:** depending on the length of the project this will be limited by the amount of class time and the length of the school year. This can be modified by making time available after school for the completion of certain aspects, but working within constraints is a good practice.

The teacher should discuss the three types of constraints and give examples where there are physical, cost and time limitations that impact design.

Suggested Student Activity

The student groups will review a sample listing of constraints for the door numbering example and then identify the constraints on their chosen design project. These should be recorded in the design portfolio.

Topic 2: Defining the Problem

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could develop the design constraints for their project. This could be done in a large group or small group setting, but should have some teacher input.

Discussion/Presentation

- Students could present design constraints to the class as a whole and take input from group discussions. This will help to refine the constraints and make the process more effective.

Research/Presentation

- Students could research a product development and outline the design constraints involved in this development. This research would involve online searching and maybe some industry contact.

Portfolio

- Students could put the research and background material they used to develop their design constraints in their design portfolio.

Resources

Topic 3: Generating Options

Outcomes

Students will be expected to

- 6.3.1 Develop alternative solutions concepts (1.402, 1.403)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

When completing a design project, the design team must develop a solution that satisfies as many of the objectives as possible within identified constraints. As they generate possible solutions to the design project, the design team must be cognizant of the objectives, related criteria and constraints. A key consideration at this stage is the importance of meeting each objective in the final solution. Generally, not all objectives are of equal importance and it may even be necessary to omit or revise objectives/criteria as the project proceeds. A number of solutions meeting different objectives/criteria in different ways may be developed. One must be chosen in the end. This is not a bad thing, although choosing which solution is the best may be a time consuming process. As well if the proposed solution does not pass its later review and evaluation an alternative will need to be available for consideration

There are a number of methods such as brainstorming that can be used to help generate alternative solutions to a design problem. Research on existing related technologies is also an important pre-requisite to alternative solution generation. The teacher should emphasize to students that engineering design is rarely aimed at invention but rather at combining and modifying existing proven technologies.

Suggested Student Activity

Each student group will brainstorm possible solutions to their chosen design project. The teacher should stress that critique of suggestions by members is not acceptable at this stage in the process. Each group will then be required to summarize the results of their brainstorming session to the class. Each group will be required to add this summary to the design portfolio.

Topic 3: Generating Options

Suggested Assessment and Evaluation Strategies

Brainstorming/Practical Activity

- Students could develop a set of solutions all meeting the design requirements for their project. This could be done in a large group or small group setting, using brainstorming as a technique, with some teacher input.

Research/Presentation

- Students could research a product development and develop their own alternative solution. This solution could be produced in a poster format and displayed in the design and fabrication area.

Portfolio

- Students could put alternative solutions in their design portfolio. It is important for this to be done so that if an alternative solution is needed there will be a good record of it.

Resources

Topic 4: Selecting the Best Option

Outcomes

Students will be expected to

- 6.4.1 Evaluate alternative solutions in terms of design objectives. (1.403, 1.404)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

During a design project the design team will generate several possible solutions to the problem. The next stage in the process is determining how well each of the solutions meets each of the objectives. Each objective has a degree of importance in the solution of the problem. For example, in the school numbering design project the size restrictions would be of more importance than the aesthetics. When listing the objectives and the associated criteria, the design team should attach a weighting system that reflects the importance of each objective. The teacher should discuss the use of a decision matrix in selecting the solution that appears to be the best option for further development.

With the school-based product weighing the design is more a matter of questioning the stakeholders rather than developing it in house as it were. Students and staff should be polled to see which of the design objectives are the most important and which the least. It is assumed that solutions that are outside the design constraints either costing too much, taking too long or being too large will be disqualified at the beginning of the process. From this weighing students could develop their decision-making model to help to choose the best solution. Once again the rejected solutions should not be discarded as they may become useful at a later stage of the process.

Suggested Student Activity

Each student group will review a sample decision matrix for the door numbering example. Students will then develop a decision matrix for their chosen project and use it to help select the preferred solution for further development.

Topic 4: Selecting the Best Option

Suggested Assessment and Evaluation Strategies

Research/Practical Activity

- Students could poll the school body to determine the weighing of the various objectives. Once doing so, they can then develop a decision-making matrix that can be used to evaluate each proposal and arrive at the best choice. A variety of examples of decision making models are available in the Career Development 2201 teacher's resource and curriculum guide.

Discussion/Presentation

- Students could champion a solution to their problem statement. They could prepare a presentation arguing for their solution and make the case in front of the class or the group that is doing this design. A winner based on the presentation and meeting the other criteria could be chosen.

Portfolio

- Students could put their evaluation and all the materials developed in the process into their design portfolio. This information may be useful at a later date if an alternative solution becomes necessary.

Resources

Career Development 2201

Curriculum Guide

Topic 4: Selecting the Best Option

Outcomes

Students will be expected to

6.4.2 Select the best alternative.
(1.403, 1.404)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Selecting the best alternative for a design problem involves picking the alternative that best satisfies all of the objectives. The best option typically scores highest on the decision matrix for objectives and criteria. In some cases, however, the best option may actually incorporate elements of several of the alternative solutions considered.

Choosing the best option requires that students think logically and be confident in their decision-making abilities. The fear of failure may make students reluctant to make decisions and the teacher must emphasize to them that this uncertainty is a normal part of the design process. They must also learn that information acquired through research and consultation with practitioners is critical to helping them make the correct decision. There is always a probability of failure but the risk of failure is reduced when students are well-informed in their chosen area of study.

The entire design process could be summed up with the cliché “If at first you don’t succeed...try, try again.” Students should be told that having a solution that is unsuccessful is almost as important as having a working one. Engineers rarely make the correct choices every time and must get used to the idea that every failure adds something to the process. It is possible that a failed solution at this stage may be used later and that elements of all alternatives may end up being part of the final solution.

Suggested Student Activity

Each student group will select the best solution option for further development and write a brief rationale specifying why this option was chosen. This rationale should be added to the design portfolio.

Topic 4: Selecting the Best Option)

Suggested Assessment and Evaluation Strategies

Portfolio

- Students could put their choice for best alternative in their design portfolio. All relevant materials should accompany the choice, as defending the choice and evaluating it at a later stage of the design process will be necessary.

Research Assignment

- Students could research a product development and how the final choice of which alternative solution was best was made. This assignment will involve some online research and maybe questioning of a local industry or design firm. A guest speaker in this area would be a useful addition for this outcome.

Presentation/Discussion

- Once a final best solution is decided upon, a discussion of how to bring the best aspects of competing solutions into the process should be undertaken. A presentation of what the best solution entails would be a good starting point, followed up by more brainstorming about how to incorporate other ideas.

Resources

Topic 5: Developing the Solution

Outcomes

Students will be expected to

- 6.5.1 Develop a production plan for prototype fabrication (1.402, 1.403, 2.401, 2.402, and 2.404)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

A prototype is the first product of a design. It is meticulously crafted and follows the design elements to the letter. It is frequently hand crafted and periodically destroyed/used up by the evaluation process. Sometimes it is to scale and sometimes it is smaller. Producing the prototype is the first step in the fabrication process, which will immediately follow the design process.

Developing a prototype design can be a complicated process involving many different disciplines including personnel from engineering, production, quality control, purchasing, and planning. The teacher should discuss with the class the importance of developing a plan that lists all required activities with associated timelines and resource requirements. This is distinctly evident in the case of CNC use, as the timing of activity on one CNC machine will be a significant bottleneck.

A production plan involves a series of planning steps

- Materials to be used,
- Processes to be used,
- Tools, equipment and machinery to be used,
- The sequence of production,
- Production scheduling,
- Timing so that prototype can be developed and evaluated and replaced if necessary.

There are a number of planning software packages available to help in this, and something like Microsoft Project, could be used at this point. Some freeware products will also do the same thing and produce the timelines and GANTT charts that will aid in planning.

Suggested Student Activity

Each student group should review a sample project plan that has been distributed by the teacher. Each group will then develop the plan for their chosen project that lists the key activities and associated timelines in the form of a GANTT chart, as well as the related resource requirements. Spreadsheet or project management software should be used for this if possible. This plan should be added to the design portfolio.

Topic 5: Developing the Solution

Suggested Assessment and Evaluation Strategies

Practical Activity/Pencil and paper

- Students could develop their own production plan for their chosen design. The plan should include all elements, such as materials, tools, timing and processes to be followed. Once completed it should be evaluated by the teacher and modified if necessary before putting into effect,

Paper and pencil

- Students could develop their own GANTT chart for their production schedule, making sure that each aspect of the fabrication takes place in the required order and timing. This chart will be their guide through the prototype production.

Portfolio

- Students could put their production plan into their design portfolio. It is important that copies are available if something goes wrong with the process so that the plan can be checked to see if the implementation or the plan were at fault.

Research

- Students could research the concept of production plan specifically with respect to prototypes. Online research or a visit to a local production facility are two methods that can be used.
- Practical Activity

Resources

Topic 5: Developing the Solution

Outcomes

Students will be expected to

- 6.5.2 Develop detail and assembly drawings for the prototype (1.405)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Before an engineered part can be made, the necessary shape, form and dimension information needed to manufacture it must be known.

In the case of assemblies that consist of multiple parts, information regarding part identity and how the various parts fit together is also required. Working drawings provide this information. A “set” of working drawings includes detail drawings, which provide the shape, form and dimension information for each part, and the assembly drawing, which identifies each part and illustrates how parts should fit together.

In this case the students, working in small groups, should each develop a detail drawing of their chosen fabrication project. The detail drawings must outline exactly what each of the part will look like. Once these are complete students will work together to develop the assembly drawing. Each part must fit exactly, and the assembly drawing must indicate where each one will reside. The concept of tolerance should enter the discussion at this point, as being too far outside the given parameters will mean an incomplete or ill-fitting part. This is good practical experience for several of the topics found in Design and Fabrication 1202.

As they develop their working drawings, emphasis should be placed on:

- Material,
- Fabrication methods,
- Operator skills,
- Time, and
- Budget.

Suggested Student Activity

Each group will develop a set of working drawings, including detail and assembly drawings, for their preferred solution. The teacher should be working only as a facilitator at this time, and students should be taking full control of the design and fabrication of their prototype.

Topic 5: Developing the Solution

Suggested Assessment and Evaluation Strategies

Practical Activity/Paper and pencil

- Students could create detail and assembly drawings of their design project. It is understood that these drawings will be used with the production plan in the fabrication of the prototype.

Practical Activity/Solid Works

- Students could create their detail and assembly drawings using Solid Works. In this way they will have an opportunity to test their assembly before production. A digital copy of this file could be printed or placed in the students digital portfolio.

Portfolio

- Students could put a copy of their detail and assembly drawings in their design portfolio.

Research Assignment

- Students could research the link between assembly drawings and production plans in industry. This research could include online searches, or interviews with production engineers.

Resources

Topic 6: Prototyping and Testing

Outcomes

Students will be expected to

6.6.1 Fabricate the design prototype (1.404)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

For both students and professional designers, this is likely the most exciting stage of the product development process where theory meets reality. Before production starts, the completed working drawings and related calculations should be re-checked for errors. The teacher should emphasize to students that they will undoubtedly encounter problems in translating the design idea to a finished product, and, in some cases, re-design may actually be necessary. Students should also be advised that when they encounter problems during production, they will have to be clearly defined and then a solution found. This will help students to develop problem solving skills. The CAM program in use in this course has a sampling program allowing for the part to be run virtually. This should also be part of the process of testing.

If a problem is discovered the production must stop. Time has to be taken to work through the problem before production continues. This will impact the production plan, and may even effect the final design. This is where having the competing designs still available may help in making changes.

Assigning jobs for each individual at this point is a good idea. Not everyone can cut, not everyone can nail and etc. Each assigned task, tool or process should have an individual assigned for fabrication. It is understood that all individuals using the fabrication equipment have been checked out on the machinery with regards to safety and have passed the requisite safety test.

Fabrication usually ends with a finish cut or detail and the prototype is no different. The finished product should be pleasing to the eye as well as following the plan as closely as possible. A little sanding, a bit of paint and the prototype is ready for viewing.

Suggested Student Activity

Each group will develop a physical prototype of their preferred solution. Any design changes deemed necessary during this process should be documented in the design portfolio and the working drawings revised as required.

Topic 6: Prototyping and Testing

Suggested Assessment and Evaluation Strategies

Paper and pencil

- Students who have not already done so must pass a safety test for the tool or machinery they are using in the fabrication process. This test must be passed at 100% accuracy for the student to be permitted to use the tool in question

Practical Activity

- Students could produce their prototype in appropriate sized groups. In each case it is expected that everyone within the group will have an equal share of the work and an equal share in the process. The fabrication should take place in an assembly fashion, with all parts being fabricated before final assembly begins.

Portfolio

- Students could place photos of their finished prototype into their design portfolio
- Students could put an entry into their course portfolio outlining their role in the fabrication process.

Research/Presentation

- Students could develop a process for checking the production process at each stage so that errors can be identified and dealt with in a timely fashion. Once this process has been developed it should be shared with the class in a presentation and a discussion could ensue. As stated before the CAM software has a test run capability which should occur before use of the CNC machinery.

Resources

Topic 6: Prototyping and Testing

Outcomes

Students will be expected to

6.6.2 Test the design prototype for functionality (1.404)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Probably the most exciting part of the design project is testing the physical prototype. As indicated earlier the value of the prototype depends on the extent that it meets or exceeds the original design objectives and criteria. Most designs do not initially meet all of the criteria since there are often unforeseen problems that do not become apparent until after prototype testing. Prototype testing can sometimes require many hours of operation under actual and/or simulated conditions. Following this the design is evaluated and areas of concern identified. Accordingly, the teacher should develop a prototype test procedure that allows students to verify whether or not their design meets functional requirements.

For the design of door numbering, installing a set of numbers on a door would be a test of functionality. The more complex the device the more complex the test will be as the full range of functionality must be tested.

Testing should be as rigorous as possible. As discussed previously some prototype testing included the ultimate destruction of the object in question. In this case though this would not be a necessary action. Students and the teacher should run their prototype through all the possible avenues, and actions by others.

The results of the testing should be well documented as these will form part of the evaluation process to follow. All observations should be recorded in detail just like an experiment. This is essentially what the testing phase is.

Suggested Student Activity

Each group will operate and test their prototype in accordance with the teacher's testing requirements. Test results should be recorded in the design portfolio.

Topic 6: Prototyping and Testing

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could test their prototype for functionality. To determine what functionality in this instance means, they need to study the design brief and the expectations of the product.

Practical Activity/Problem Solving

- As students test their prototype, small inconsistencies or problems may become obvious. Students could identify these problems and work through the design process to solve them. Aspects of unsuccessful competing product designs could be used to solve these problems if necessary.

Portfolio

- Students could complete their testing and record the results and changes made to the original design and place them in the design portfolio.

Resources

Topic 7: Evaluation and Redesign

Outcomes

Students will be expected to

- 6.7.1 Evaluate the prototype in terms of design objectives (1.404)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

As indicated earlier the success of the prototype depends on the extent that it meets or exceeds the original design objectives and criteria. Those criteria were established earlier in this unit and should be stored in the design portfolio. A simple yes or no question in each case should be sufficient.

For example, if the students are making door numbers, the design objectives could be something like this:

- To fit on the door,
- Large enough to be seen,
- Sturdy enough to stay on the door, and
- Not be so large as to impeded door opening.

Asking each of these as simple question will determine whether or not each was met.

Design objectives were one part of the determination process, but so were design constraints. Although the chosen design would have had to address these constraints, now that the prototype is finished making sure the constraints have been addressed is also part of the evaluation process.

The constraints were:

- Costs - now that the prototype is done a more accurate cost estimate should be available
- Time - although the prototype is done very well rather than very quick, an estimate of the time for fabrication should be made
- Size - designed size and actual size are sometimes different, the prototype will give the most accurate representation

Suggested Student Activity

Each student group will evaluate their design prototype by comparing to a check list of the original design objectives, criteria and constraints. Based on this evaluation, students should note areas for improvement. Completed evaluations and noted improvements should be recorded in the design portfolio.

Topic 7: Evaluation and Redesign

Suggested Assessment and Evaluation Strategies

Portfolio

- Students could complete their evaluations and any noted improvements and place them in the design portfolio.

Practical Activity

- Students could test their prototype in terms of the design objectives. A simple chart asking each objective as a question and then responding to the question will serve the purpose.

Paper and pencil/Group Activity

- Students could develop a chart that will allow them to evaluate their prototype properly in terms of design objectives. This chart could be as a group activity and then shared within the class.

Practical Activity/Discussion

- Students could evaluate their design constraints along with their prototype, discussing whether their constraints were properly formed and created. This can also form the basis of the final evaluation.

Resources

Topic 7: Evaluation and Redesign

Outcomes

Students will be expected to

6.7.2 Evaluate the prototype performance based on testing (1.404)

6.7.3 Suggest any required modifications (1.404, 2.403)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

The degree of success of a design is based on how well it meets or exceeds the design objectives. In practice, this assessment involves actual testing of the physical prototype to determine if it functions as intended. There is always room for improvement in a design and any needed improvements should be discovered when the prototype is tested. This is what comes of the evaluation.

An evaluation takes all the observations, all the results, all of the checklists as a whole and makes a definitive conclusion. For this type of evaluation we must review our problem statement, the results of the functionality tests, the design and the prototype in terms of these concerns; and make a decision as to whether the tests supported this design or not. We evaluated already in terms of our design objectives, and this will be added to the final decision.

In industry a series of tests are used in the evaluation process, and the results from each are used to form a conclusive pass/fail result. Each of the tasks tests a different aspect of the prototype and even a negative result can have positive implications.

Suggested Student Activity

Each student group will analyze their prototype test results with areas for improvement should be noted in the design portfolio.

Teacher Preparation

Since most initial designs do not initially meet all objectives and criteria, there are typically modifications required. Sometimes problems are not apparent until after the product is mass produced and feedback is received from consumers. The teacher should emphasize to students that design problems should be corrected at the earliest possible stage because the potential negative impact on product cost, user safety, and overall product quality increases in severity with each successive step in the design process. The student must also be reminded of the importance of getting objective opinions from 3rd parties, ideally potential end users, and being professional when critiques are offered. Modifications do not mean that the design is a flop or has to be discarded. This is the main reasons we kept the information from the competing designs, as elements of them could easily be incorporated into the current design. Students at this point have to be reassured that failure of this sort of testing is not the end but only part of the process.

Suggested Student Activity

Using the results of the design evaluation and prototype testing, the student groups will suggest design modifications. Suggested modifications should be recorded in the design portfolio.

Topic 7: Evaluation and Redesign

Suggested Assessment and Evaluation Strategies

Design Process/Discussion

- Students could determine whether or not their chosen design has passed or failed at this point. If it does not meet enough of the objectives or failed its functionality test then at this point consideration of whether to stick with this design should be made. This could take place in a group or class discussion.

Research assignment

- Students could research the testing done in industry and how the evaluation process uses these results.

Discussion

- Students could discuss the results of the testing and the objective evaluation in total and whether there could be a better way to do an evaluation. The discussion could include students suggesting other ways of testing or tests that could have been done but were not to strengthen or weaken the outcome.

Practical activity/Discussion

- Students could discuss the results of the testing and evaluation procedure. Although discarding the design is an option and one which has been discussed before, modification is a much simpler process that would not require as much time and energy. This should be discussed with students as a viable option.

Research/Presentation

- Students could research a product in industry that had been modified after prototyping. This very well could include any product on the market, but students should zero in on one that the information is available for. A presentation to the class on the process this product went through should be made.

Portfolio

- Students could put the results of the evaluations and any resultant modifications in their design portfolio.

Resources

Design and Fabrication 1202

Teacher's Resource Guide

Design Portfolio

Topic 7: Evaluation and Redesign

Outcomes

Students will be expected to

- 6.7.4 Identify the entrepreneurial opportunities for the project (4.402)

Elaborations - Strategies for Teaching and Learning

Teacher Preparation

Engineering is the application of science to the solution of practical problems and that is where design work originates. Individuals and groups design products and systems in response to some real or perceived need in society. Engineering consulting firms are generally involved in applying the design process to technical problems with a view to making a profit at the end of the day. There are numerous entrepreneurial opportunities related to design in such areas as selling design concepts, setting up production facilities, establishing distribution networks, product marketing, production system maintenance and material/equipment supply.

Within the school environment students should be asked to extend this thought beyond entrepreneurial consideration. Fund raising could be one such idea, how can we use this design to make funds for the school. Another opportunity, much simpler but more altruistic would be how can we use this design, the processes we have learned to make improvements to our school. The in school design activity would support this. Students could become more involved in the betterment of their school, and in some ways feel pride in their accomplishments and a sense of true belonging.

The teacher should provide local examples of how design supports entrepreneurship.

Suggested Student Activity

The students should determine the possible sales and other economic opportunities for their project. They should conduct a small market survey to determine the acceptability of their project. The students should generate a list of the direct economic benefits of their project and any potential spin off benefits.

This list should be recorded in the design portfolio.

Topic 7: Evaluation and Redesign

Suggested Assessment and Evaluation Strategies

Practical Activity

- Students could develop a plan for promoting the entrepreneurial aspects of their product. This could involve discussions with the Enterprise teacher or even with various youth entrepreneur groups such as Junior Achievement of the Y-Enterprise center.

Paper and pencil

- Students could develop a series of questionnaires and polls to give the staff and their peers at their school to identify other projects they could create to help improve their building. These could form the basis of future projects in the Design and Fabrication Lab.

Resources

Design Portfolio

Unit 7

Careers in CAD/CAM/CNC

Purpose

UNIT 7.0 introduces students to the wide variety of challenging and rewarding career options related to CAD/CAM. Typical roles performed during the CAD/CAM process are reviewed and students explore the related employment statistics and educational requirements through completion of the following sub-units:

- 7.1 Careers in CAD/CAM/CAE
- 7.2 Careers and Employment Statistics
- 7.3 Education Programs and Entry Prerequisites
- 7.4 Industry Case Study

Profile

CAD/CAM is an exciting dynamic field of study that seamlessly integrates knowledge of both engineering design and manufacturing in the production of a part. CAD/CAM Software and CNC machines are continuously evolving and this requires the CAD/CAM practitioner to become a lifelong learner. The dynamic nature of this career field is a constant motivator for the CAD/CAM practitioner to upgrade skills and knowledge. This UNIT requires students to identify the available job roles in the CAD/CAM field, research related employment statistics and future prospects, and determine the educational qualifications needed to work in this area. An industry case study is also used to help illustrate the various job functions that are performed in support of CAD/CAM.

Implementation

UNIT 7.0 is intended as a self-directed study unit with students working independently. The teacher should take on the role of facilitator providing direction and guidance as required.

Evaluation

This unit should constitute less than 5% of the course time and the evaluation should reflect this

Topic 1: Careers in CAD/CAM/CNC

Outcomes

Students will be expected to

7.1.1 Identify the various career roles in CAD, CAM, CNC, and CAE [4.401, 4.403]

7.1.2 Summarize the primary duties and responsibilities associated with each of the primary career roles in CAD, CAM, CNC, and CAE [4.401, 4.403]

Suggested Teaching and Learning Strategies

Teacher Preparation

There are a variety of available career roles related to CAD, CAM, CNC, and Computer Aided Engineering (CAE) ranging from 2D CAD drafter to professional engineers. While the teacher should provide students with direction on potential sources of career related information for this field, such as Internet sources, government departments, and local industry, this sub-unit should be a student driven exercise. Following completion of the student group activity, the teacher should query the groups in an effort to develop a “master” list of potential career paths in this field.

Identification should take the form of a list specifically, rather than an in depth look at any individual career option.

Teacher Preparation

Once a list is compiled above, the next step in reviewing career possibilities is to garner an outline of what each position may entail. Careers in this area vary widely, and students should be aware of this fact. More duties usually means more responsibility, but invariably also means more recompense.

Students should also become aware of the variety of careers that, although they are not specific to CAD/CAM/CNC, may involve the use of one or more of the skill sets involved.

This should be stage two of the career research into CAD/CAM/CNC. Each of the outcomes in this unit are leading students towards developing the knowledge to put together a comprehensive career profile, much as is done in Career Development 2201. Students should be familiar with this process and should be able to transfer it to this situation.

At the end of this outcome a repository of profiles should be available and stored in the skilled trades suite for future reference.

Topic 1: Careers in CAD/CAM/CNC

Suggested Assessment and Evaluation Strategies

Research/Discussion

- In groups of 2 or 4, students could research the various career roles related to the CAD/CAM field with a view to identifying the primary duties and responsibilities. Group results could then be compiled, through an interactive discussion with the teacher, into one “master” list.

Research Assignment

- Students could create a career profile of a specific career in CAD/CAM/CNC. This profile could then be placed in class such that it would be accessible to other students. For examples, refer to the Career Development course materials.

Resources

- National Occupation Classification list found at: www5.hrsdc.gc.ca/NOC/
- Career Development 2201 Teacher’s Guide

Topic 2: Careers and Employment Statistics

Outcomes

Students will be expected to

7.2.1 Analyze employment statistics for each of the primary career roles in CAD, CAM, CNC, and CAE [4.401, 4.403]

Suggested Teaching and Learning Strategies

Teacher Preparation

Employment statistics can be found in a number of places but as in all research to be carried out they should be accepted only from reputable ones. The first step in analyzing any statistics is to verify the veracity of their source. This is simply done by staying with the most reputable, mainly government or government sponsored agencies.

Once the veracity is established then what questions will be asked to analyze the available numbers is the next thing to establish. In *Career Search 2008* published by the Department of Education, the following main topics were researched:

- Employment status - full-time, part-time, in school ,etc.
- Weekly wage
- Time to get first employment
- Geographical area where hired

These are not the entirety of question that could be asked for an analysis, but rather a sample.

An important fact to point out to students is that some jobs, although not specifically CAD/CAM/CNC would involve a significant amount of work in this area. As an example, engineers and engineering technologists find themselves working with these materials on a regular basis. For completeness sake research into these areas of employment, and specifically those specialties that involved CAD/CAM/CNC would be necessary.

Student Activity

In groups of 2 or 4, students research job ads and employment statistics related to the CAD/CAM field. Group results are then compiled, through an interactive discussion with the teacher, into one “master” list.

Topic 2: Careers and Employment Statistics

Suggested Assessment and Evaluation Strategies

Research/Presentation

- Students could, using the list of careers generated in the previous outcome, give hiring outlooks for the variety of careers available in the CAD/CAM/CNC area. This could be then presented to the class as a whole.

Research Assignment

- Students could compile a list of the careers that may involve CAD/CAM/CNC peripherally, but not involve specific training and use of the materials in question. This list could be added to others created in this section for completeness.

Discussion

- Students could, in small groups, discuss the opportunities in this field with an eye on how someone with this career path could gain employment or create employment in this province. A variety of products and services could be planned for as well.

Resources

- Career Search 2008
- Career Development 2201 teacher guide
- Career Cruising
www.careercruising.com
- <http://www.statcan.gc.ca/>

Topic 3: Education Programs and Entry Prerequisites

Outcomes

Students will be expected to

- 7.3.1 Compare and contrast the entrance requirements for enrolment in post-secondary studies in a CAD, CAM, CNC, or CAE related field [4.401, 4.403]
- 7.3.2 Summarize the key topics of study in a post-secondary program of study aimed at a career in CAD, CAM, CNC, and CAE related field [4.401, 4.403]

Suggested Teaching and Learning Strategies

Teacher Preparation

One of the intended outcomes of completion of Design and Fabrication 2212 is for students to acquire an awareness of related careers and insight into the post-secondary educational path that will best prepare them to work in the CAD/CAM field. In this topic students, once again through self-directed study, are required to identify and briefly describe post-secondary programs of study that will prepare them for a career in this field. Students are also required to determine the entrance requirements for these post-secondary programs, and subsequently identify the high school courses that must be completed in order to meet these entrance requirements.

The second outcome is designed to show students what they are currently studying in school and in this course specifically is relevant to career options and future studies. Looking at the key topics in a program, based on course names or topic names, should show the parallel nature of this program as a whole.

A more in depth study of these post-secondary programs will also allow students to identify some of the other aspects of studies in this area. Some of the programs are degrees, some are college based and some are apprenticeships. The level that students want to be involved in the use of CAD/CAM/CNC will determine the program that will be best suited to them.

While the teacher should provide students with direction on potential sources of this information, this sub-unit should be a student driven exercise. Following completion of the student group activity, the teacher should query the groups in an effort to develop a “master” list of post-secondary programs and related entrance requirements.

Suggested Student Activity

In groups of 2 or 4, students research post-secondary programs along with the entrance requirements related to the CAD/CAM field. Each group will compile these results through an interactive discussion with the teacher into one “master” list.

Topic 3: Education Programs and Entry Prerequisites

Suggested Assessment and Evaluation Strategies

Research/Presentation

- Students could search a variety of post-secondary institutions web sites concentrating on those which offer some program that is either directly or peripherally involved with CAD/CAM/CNC. Engineering, engineering technology, drafting, CAD programs, CNC operator, CAM programs, are some of the areas they could search for. Once they have identified a list of schools offering such programs, they can contribute to the class in a presentation sharing this information.

Research Assignment

- Students could pick one post-secondary program from their list of possibly schools and do an in depth profile of the program. This profile could either become part of the students course portfolio or handed in as an assignment. This profile could include but is not limited to:
 - Entrance requirements
 - Type of program (apprenticeship, etc.)
 - Length of program
 - Cost of program
 - Topics covered
 - Certification offered

Design Portfolio

- Students could put their list of appropriate post-secondary programs and schools in their design portfolio.

Resources

- Career Cruising
www.careercruising.com
- Various university web sites
www.mun.ca for example
- Various college web sites
www.cna.nl.ca for example

Topic 4: Industry Case Study

Outcomes

Students will be expected to

7.4.1 Identify a (local) company involved in CAD, CAM, CNC, or CAE [4.401, 4.403]

7.4.2 Define the roles and duties of the various employees in a (local) company involved in CAD, CAM, CNC, and CAE [4.401, 4.403]

Suggested Teaching and Learning Strategies

At this stage in the unit, students will have acquired insight into the type of careers, primary duties performed and the related educational requirements for the various available roles in the CAD/CAM field. Using a case-study or consultation with CAD/CAM practitioners in local industry, the students are required to develop an employee hierarchical tree that identifies the various positions and associated responsibilities for a real company involved in this field. In support of this, the teacher should arrange access to a case study resource and/or local industry representative currently employed in this area. A guest speaker from industry should also be considered for this sub-unit.

One of the first steps in this topic should be to have the class brainstorm what kinds of companies would use CAD/CAM/CNC. Many companies use one, the CAD, but not many use all three. The brainstorming session could include a discussion of the types of things CNC would be good for in industry and what types of industries lend themselves to CNC. From this list looking at local companies in the yellow pages is a good next step. Teachers should be careful not to lead their students too much in this activity as well as insuring that non-obvious CNC companies are left out. Some industry areas that should be researched include but are not limited to:

- Furniture manufacturers
- Sign makers
- Cabinet makers

Suggested Student Activity

In groups of 2 or 4, students will develop an employee hierarchical tree that identifies the various positions and associated duties in a local company directly involved in the CAD/CAM field.

Topic 1:

Suggested Assessment and Evaluation Strategies

Guest Speaker

- This can be either a teacher-directed or student-directed exercise. Students could identify a local company involved in the CAD/CAM/CNC process and contact them looking for information and a guest speaker. The arrangements for the speaker should be vetted by the teacher but the organization should be left up to the student.

Research Assignment

- Students could research a local CNC company with the goal of creating an industry profile of that company. The profile should include but is not limited to:
 - Type of business (manufacturing, etc.)
 - Use for CNC
 - Number of CNC operators
 - Use of CAD/CAM
 - Number of CAD/CAM operators

Students could either present this profile to the class or pass it in as a written assignment

Resources

- Regional Career Information Officers
- Career Work Centers
- Yellow Pages
- Business Guides

