DESIGN AND PRODUCTION OF A BICYCLE PEDAL FOR BMX BIKES

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Instructor Summary: *Design and Production of a Bicycle Pedal for BMX Bikes*

This document provides instructor guidelines for one of the ten integrated curriculum projects developed for the NSF-funded Necessary Skills Now (NSN) project (award #1501990). The NSN project partners consist of CORD and three national centers supported through the NSF's Advanced Technological Education (ATE) program: National Center for Systems Security and Information Assurance (CSSIA), Florida Advanced Technological Education Center (FLATE), and South Carolina Advanced Technological Education National Resource Center (SC ATE). The NSN project is designed to integrate employability skills into technical exercises, activities, and labs. The project partners created self-contained instructional modules vertically aligned to associate degree programs in **mechatronics/automation in manufacturing** and **cybersecurity in information technology**. (The activities described in this document support courses in manufacturing.) Six categories of employability skills, repeatedly mentioned in workforce surveys and research reports, served as the focus of the integrated curriculum:

skill category 1 TEAMWORK	*skill category* 2 PROBLEM SOLVING	*skill category* 3 VERBAL COMMUNICATION
skill category 4 WRITTEN COMMUNICATION	*skill category* 5 DEPENDABILITY/WORK ETHIC	*skill category* 6 PLANNING AND ORGANIZING

Project Overview

Purpose

The purpose of the project described in this module is to integrate employability skills (teamwork, problem solving, verbal communication, written communication, dependability/work ethic, and planning and organization skills) into activities related to the design and basic quality control for production of BMX bicycle pedals.

Courses for Implementation

- Introduction to AutoCAD
- Introduction or Fundamentals of Engineering
- Advanced technology concentration courses
- Manufacturing concentration courses
- Quality control courses

Key Terms/Major Topics

- Bicycle pedal for BMX bikes (basic definition, function, operation, general technical specifications)
- Computer-aided design (CAD)
- Computer-aided manufacturing (CAM)
- Statistical process control (SPC standard) as quality control tool widely used in industry for manufacturing processes
- Conversion between system units (inches versus millimeters)
- Basic computer numerical control (CNC) programming, software- and hardware-associated CNC programming standards
- Mechanical properties of materials (ASTM standards)

Discussion

Industry Scenario

Because of the diversity of today's cycling sports and the corresponding variations in bicycle models, there is a broad range of possibilities in the design and manufacture of bicycle components.

The type of cycling sport determines the type of bicycle used and what specialty components are needed. For example, different styles of pedals (clip, cage, platform, etc.) are fabricated to support different types of cycling. Even within a given style of pedal, there can be a large variety of options.

A BMX bicycle is an off-road sport-type bicycle. BMX bicycles are manufactured for many venues, including racing, dirt, park, and street tracks. All components of BMX bicycles, including pedals, are designed for strenuous use. Manufacturers must consider strength and durability, but also foot traction, weight, and overall style and finish.

A manufacturer of bicycle parts has recently been contracted to create a BMX bicycle pedal that meets certain mechanical and quality requirements. Students will assume the roles of the technicians, technologists, and engineers who compose the team in charge of the process.

Student Learning Objectives

Technical

- Students should be able to use computer-aided design and manufacturing tools and CNC programming tools to design and manufacture a BMX bicycle pedal.
- Students should be able to perform conversions between different measurement units used in manufacturing.
- Students should be able to analyze the pedal manufacturing process using a statistical process control tool, for quality assessment purposes.
- Students should be able to synthesize a formal presentation from information obtained through project assignments.

Written Communication

- Students should be able to read and understand written procedural guidelines.
- Students should be able to create well-written entries for project data collection.
- Students should be able to present results of designs using graphical and written communication tools.
- Students should be able to provide well-written presentation documents.

Verbal Communication

- Students should be able to demonstrate effective verbal communication skills in providing and responding to verbal directions.
- Students should be able to demonstrate effective verbal communication skills in presenting a team project.

Teamwork

- Students should be able to work in a variety of team roles to design and manufacture a BMX bicycle pedal.
- Students should work to promote the success of the team.

Dependability and Work Ethics

- Students should demonstrate dependability and work ethic while working as team members.
- Students should punctually attend all course sessions and complete course requirements on time.

Planning and Organizing

- Students should demonstrate the ability to collaborate with their team members in creating and organizing their project activities and final presentations.

- Students should be able to organize data in a clear and precise manner.

Problem Solving

- Students should be able to use statistical process control tools for quality assessment purposes.
- Students should be able to solve measurement conversion problems.

Teaching Strategies

This project is divided into four main activities:

Activity 1: Design the part using CAD/CAM tools (AutoCAD 2017), following given technical specifications and using two units of measurement (millimeters and inches).

Activity 2: CNC programming will be used (including specific hardware and software tools) for production of the CAD-designed part (designed in Activity 1). During this activity, the project team uses previously collected data to provide general guidelines for the correct connection process for CNC hardware. (Steps for the connection of the hardware should be analyzed and organized prior to final execution.) Several samples of the pedal will be produced.

Activity 3: Quality control for the bicycle pedals produced in Activity 2. The company is known for its expertise in using statistical process control (SPC) as a tool for quality assessment (working with tolerances and different Cpk indicators, for example, 1.33, 1.67, and 2.0).

Activity 4: Each team will deliver a presentation to the CEO of the company for final approval of the pedal. Teams will introduce the main ideas for the project as well as the main details of Activities 1, 2, and 3. Teams are responsible for contacting the A/V department to ensure that the presentation's technical requirements (video projector, computer, etc.) are met. The instructor may choose to introduce a "bug" or technical problem with the presentation equipment (e.g., unplugged or switched video projector/computer cables) for the presentation team to work through and solve. Teams should be advised to expect the unexpected and plan accordingly. For example, they should do a trial run of the equipment, and, in the event that an equipment problem cannot be solved, they should have printed copies of their presentations on hand as a backup.

If time does not allow for completion of all suggested activities, instructors may choose to infuse selected activities into their curricula.

Instructors should review the industry scenario and reflect on its importance to the overall project. The scenario should serve as an authentic frame of reference that enables students to experience "real-world" situations in the manufacturing industry. An industry scenario can help students become more aware of the skills that manufacturing employees (engineers, technologists, technicians, etc.) should possess. Industry scenarios provide a link between academic activities and situations that students may later experience as employees in manufacturing environments.

Instructors should emphasize the employability skills that students are working on during project activities. At the end of each class session, instructors are encouraged to ask students to reflect on the employability skills they are practicing.

Student/Group Activity Steps

ACTIVITY 1

Design the part using CAD/CAM tools (AutoCAD 2017), following given technical specifications and using two units of measurement (millimeters and inches).

Estimated duration: 10 class hours + 2 hours printing of layouts

Activity Preparation

Instructors should reserve lab facilities as needed and make sure all necessary software (AutoCAD 2017), equipment, and materials are available.

If a learning management system (LMS) such as Blackboard or Moodle is available, instructors should post in advance the introductory PowerPoint file 2 What Is a CAD/CAM Software Using AutoCAD – Activity 1.pptx. During the class session, the instructor should present the PowerPoint to provide a general overview on what AutoCAD is and how CAD/CAM tools will be helpful in the design of the bicycle pedal. If an LMS is being used, a link for AutoCAD file submission can be created.

Instructors should provide printouts of 3 MX Bike Pedals Specifications – Activity 1.pdf. During the class session instructors should review this file to provide students with basic information on BMX bicycle pedal specifications.

Instructors should hand out 4 Problem Solving Template - Conversion Millimeters to Inches - Activity 1.pdf. During class, students should fill out the corresponding information as an in-class problem-solving exercise.

Instructors should hand out 5 Assessment Tool for CADCAM Design and Unit Conversion - Activity 1.pdf.

Instructors should complete 6 Student Evaluation - Activity 1.pdf.

Instructors should post an announcement regarding a quiz covering basics of AutoCAD design and conversion between mm and inches, to be taken by each student during the next class meeting. (30% of total project)

Activity Steps

Instructors should assign students to teams or ask students to create teams of two or three students each and explain that these teams will work together for the duration of the project. Students will assume the roles of technicians, technologists, or engineers.

Instructors should explain to the teams the basic specifications for the pedals as they appear in 3 MX Bike Pedals Specifications – Activity 1.pdf. Instructors should also explain the basics of AutoCAD 2D and 3D, including how to use dimensions, basic drawing commands, and other relevant topics.

Instructors should ask every team to solve the problem of converting inches to mm and vice versa. Instructors should handout copies of the file 4 Problem Solving Template - Conversion Millimeters to Inches - Activity 1.pdf, which explains a simple but effective conversion technique. Students will complete calculations using the template. Each team will deliver one completed document to the instructor for grading.

During Activity 1, instructors should remind students that in manufacturing—a worldwide industry—product specifications can be expressed in different units. For example, if a bicycle part manufactured in this country is to be sold overseas, the specifications will be expressed in metric units. In that case, the people involved in manufacturing the product should be able to solve problems involving inches and mm.

Finally, teams will work on the AutoCAD 3D pedal design, taking into account the pedal's technical specifications, delivering two DWG files and a printed version. In each DWG file, every team should include two layouts for the final deliverable (one layout with the title of the design and student names, a second layout with a viewport with the bicycle's pedal and corresponding dimensions). One DWG file should show the dimensions in inches, and the other DWG file should show the dimensions in mm.

Instructors should explain to teams that people in manufacturing industries should be able to present results of designs using both graphical and written communication tools. Each team will provide a short presentation of results to the class.

ACTIVITY 2

CNC programming will be used (including specific hardware and software tools) for production of the CAD-designed part (designed in Activity 1). During this activity, the project team uses previously collected data to provide general guidelines for the correct connection process for CNC hardware. (Steps for the connection of the hardware should be analyzed and organized prior to final execution.) Several samples of the pedal will be produced.

Estimated activity duration: Over the course of one to two weeks depending on lab/milling machine availability

Activity Preparation

Instructors should ensure that a milling machine and associated software are available for use. Instructors should also ensure that the necessary tools for measurement are available in the lab (micrometers, tape).

Instructors should give students access to the milling machine's user manual. A printed version of this manual should be available in the laboratory, and electronic versions should be accessible in an LMS.

Instructors should assign students to teams and explain that these teams will work together for the duration of the project. Students will assume roles of technicians, technologists, or engineers.

Instructors should present the PowerPoint presentation 7 Basics on CNC Programming - Activity2.pptx.

Instructors should review 8 Milling Machine Set Up and CNC Programming - Activity 2.pdf.

Instructors should provide copies of 9 Materials for Bike Pedal - Activity 2.pdf.

Instructors should complete 10 Student Evaluation - Activity 2.pdf.

Instructors should also coordinate with students to assign sufficient time for each team to meet in the laboratory to use the milling machine.

Activity Steps

Teams will implement basic CNC programming by using a milling machine with hardware-appropriate connections and associated software. Instructors should provide an overview of what CNC is and how to set up the milling machine, which is one application of CNC programming.

When providing directions for the milling machine, instructors should make a mistake (on purpose) in two of the steps (reversing the order, for example) for the machine setup. Each team should analyze the situation and correct the order of steps. Student teams should deliver the final set of correct instructions by completing the corresponding spaces in 8 Milling Machine Set Up and CNC Programming - Activity 2.pdf. Instructors should emphasize the importance of clear instructions and written communication. Caution should be exercised in the

programming. If there is a mistake in the CNC program, the team should dry run the program BEFORE cutting. A mistake in a CNC program, if undetected prior to cutting, can damage the machine tool. Consider running wax material (instead of aluminum) in the proving-out portion of setup.

Next, instructors should pose questions. Examples: Which types of materials may be used in the production or manufacturing of the pedal in the manufacturing industry? Does a different material affect feeds/speeds/depth of cut in the manufacturing process of a pedal? Do different materials require different machining parameters?

Students should analyze different material use and its impact on the manufacturing of the bike component. Instructors should review examples related to different types of generic materials. (Example, using aluminum as a generic material: A harder grade of aluminum takes a longer time to machine, so an option for pedal material would be virgin aluminum, since this type is easier to machine in comparison with 6061 aluminum.) Instructors should explain to the students that they should never make assumptions about machinability. Students should learn to evaluate the performance of different materials. Students should complete 9 Materials for Bike Pedal - Activity 2.pdf. Since this is an academic exercise, the material that can be used in the laboratory will be the one available in the milling machine (i.e., wood).

Finally, each team will upload its pedal design by using the corresponding file in the milling machine software (CNC software for this project). Students will set up the machine and produce at least three pedal samples (using wood-type materials).

ACTIVITY 3

Quality control for the bicycle pedals produced in Activity 2. The company is known for its expertise in using statistical process control (SPC) as a tool for quality assessment (working with tolerances and different Cpk indicators, for example, 1.33, 1.67, and 2.0).

Activity Preparation

Instructors should reserve lab facilities as needed and make sure all necessary equipment and materials are available.

Instructors should assign students to teams and explain that these teams will work together for the duration of the project. Students will assume roles of technicians, technologists, or engineers.

Instructors should provide copies of 12 SPC Tool for Bike Pedal Quality Control - Activity 3.pdf.

Instructors should provide copies of 13 Calculations for Bike Movement - Activity 3.pdf.

Instructors should remind students that Quiz #1 will take place at some specified time.

Instructors should present the PowerPoint titled 11 SPC for Bike Pedal Quality Control - Activity 3.pptx to give students a general overview of SPC and how this tool is helpful in bike pedal design.

Activity Steps

Each team will use the SPC tool to assess the quality of the pedal produced in Activity 2. Instructors should explain to students that they should develop an analysis for holding a closer SPC Cpk on a dimension that proves more reliable and accurate compared to the original design that resulted from Activity 1. Instructors should explain that without the ability to test the final component, there is no way to measure its performance. This would present more open tolerances in a subgroup that would give a lower Cpk. Testing

would then be done with a given measurement data set. Teams will study the quality based on different Cpk values provided by the instructor (higher or lower) and different data sets with different materials. The class as a whole should decide what Cpk and material would be chosen for the final design.

This analysis involves differences between materials as a criterion. (For example, different aluminum alloys will have different resultant characteristics.) Aerospace aluminum has high strength characteristics. This is what a high-end bicycle pedal would be made from.

Instructors should debrief with all students after teams have completed the production of pedals. During that class session, instructors should provide copies of 14 Quiz #1 to Evaluate Activity 1 and Activity 2.pdf.

Instructors should lead the class in a review of 13 Calculations for Bike Movement - Activity 3.pdf. Now that students have made key decisions on the design and manufacture of their bike pedal, they can envision a bike working with the pedal they created, and they may be able to analyze in general some of the parameters (velocity, height, impulse, etc.) that are studied when BMX bikes are used (in movement).

ACTIVITY 4

Each team will deliver a presentation to the CEO of the company for final approval of the pedal. Teams will introduce the main ideas for the project as well as main details of Activities 1, 2, and 3. Teams are responsible for contacting the A/V department to ensure that the presentation's technical requirements (video projector, computer, etc.) are met. The instructor may choose to introduce a "bug" or technical problem with the presentation equipment (e.g., unplugged or switched video projector/computer cables) for the presentation team to work through and solve.

Activity Preparation

Instructors should reserve lab facilities as needed and make sure all necessary equipment and materials are available.

Instructors should assign students to teams and explain that these teams will work together for the duration of the project. Students will assume roles of technicians, technologists, or engineers.

If instructors choose to introduce a technical "bug" for students to work through, this should take place shortly before the teams' presentations.

Optional: Instructors can upload the presentations through an online LMS.

Activity Steps

Each team will make a formal presentation of results from Activities 1, 2, and 3.

Students should be advised that during their presentations, they might encounter technical problems created by the instructor on purpose (e.g., disconnected projector cable). Teams should devise plans for addressing unforeseen technical issues (e.g., bringing printed copies or flipchart versions of their presentations). Instructors should evaluate how well teams managed technical difficulties.

Expected Results

ACTIVITY 1

Each team will produce:

- Two (2) AutoCAD files with corresponding 11x17 printed versions of layouts (one showing the title of the design and students' names, the other showing the pedal and its dimensions). Each team will present four printed documents or layouts, two layouts per DWG file. (10% of total project)
- Completed problem-solving template with the solution to the problem of converting inches to millimeters (showing all calculations) (10% of total project)
- Completed document related to the assessment tool for 3D design and conversion between units (10% of total project)
- Formal presentation to the class (5% of total project)

ACTIVITY 2

- Three (3) bike pedals produced by milling machine (15% of total project)
- Completed 8 Milling Machine Set Up and CNC Programming - Activity 2.pdf (15% of total project)

ACTIVITY 3

- 12 SPC Tool for Bike Pedal Quality Control - Activity 3.pdf (15% of total project)
- Quiz#1, as announced in Activity 1 (10% of total project)

ACTIVITY 4

- Formal PowerPoint presentation given to class and posted on LMS (10% of total project)
- 15 Instructor's Observations - Activity 4.pdf

Equipment/Materials

Standard classroom technology equipment (computer, projector, etc.)

Computer with CAD/CAM software (AutoCAD 2017 recommended)

Computers with presentation software (Microsoft PowerPoint, Apple Keynote, Powtoon, Prezi, etc.)

Plotter or printer

Milling machine

3D printers

Micrometers

Measurement tapes

Instructor Resources

Background Materials

Prerequisites: Algebra, geometry, Microsoft Word and PowerPoint, basic knowledge of milling of materials, basic knowledge on CNC programming

Handouts and Supplemental Materials

2 What Is a CADCAM Software Using Autocad - Activity 1.pptx

3 BMX Bike Pedal Specifications - Activity 1.pdf (3D rendering for bike pedal provided by Kyle Simpson, Palm Beach State College)

4 Problem Solving Template - Conversion of Millimeters to Inches - Activity 1.pdf

5 Assessment Tool for CADCAM Design and Unit Conversion - Activity 1.pdf

6 Student Evaluation - Activity 1.pdf

7 Basics on CNC Programming - Activity 2.pptx

8 Milling Machine Set Up and CNC Programming - Activity 2.pdf

9 Materials for Bike Pedal - Activity 2.pdf

10 Student Evaluation - Activity 2.pdf

11 SPC for Bike Pedal Quality Control - Activity 3.pptx

12 SPC Tool for Bike Pedal Quality Control - Activity 3.pdf

13 Calculations for Bike Movement - Activity 3.pdf (provided by Frank Anderson, former high school physics teacher)

14 Quiz #1 to Evaluate Activity 1 and Activity 2.pdf

15 Instructor's Observations - Activity 4.pdf

Websites

AutoDesk– AutoCAD
http://www.autodesk.com/education/free-software/AutoCAD

Statistical Process Control (SPC) Overview and Glossary
http://www.statisticalprocesscontrol.info/glossary.html

Process Capability Index, Cpk Overview
http://www.six-sigma-material.com/Cpk.html

Link to Examples of Free CNC Programming Software
https://www.reference.com/technology/examples-cnc-programming-software-d0dfacf0e0a6ba8d

Assessment

Students should be assessed according to their completion of the tasks and deliverables. Teams should fill out and complete the corresponding forms or documents as required in the activities. Suggested grade-weight percentages have also been provided.

Instructors should grade and provide feedback on the team activities. Each student will receive a grade based on individual results and team collaboration. Instructors can use the provided student evaluation documents as support for grading.

The following assessment tools have been provided:

6 Student Evaluation - Activity 1.pdf

10 Student Evaluation - Activity 2.pdf

14 Quiz #1 to Evaluate Activity 1 and Activity 2.pdf

15 Instructor's Observations - Activity 4.pdf

Instructors should feel free to create additional assessment tools such as those listed below:

- Additional rubrics
- Performance task checklists
- Observations
- Quizzes, tests
- Writing prompts
- Laboratory reports