Increasing Mechanical Engineering Technology Students' Competency, Interest, and Motivation in Manufacturing through a Repetitive Process-Based Approach.

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Abstract

High quality manufacturing, specifically Computer Numerical Control (CNC) programming, turning, and machining, is difficult to simulate at the university level. Typically, single part projects are assigned, programmed, machined, and lastly, graded by the professor. The problem with the typical method is the "A" through "F" grading structure used at most institutions. In industry, a "C" grade part does not pass quality control; however, in education, the "C" grade is passing. Standard grading creates a low stakes environment, which encourages some students to produce average work for a low end passing grade and thus, struggle when introduced to their first industry job where quality standards must be high.

Quality of parts is difficult to achieve as students first learn to manufacture, and often creates frustration and a lack of interest for students. The repetitive process-based approach starts students off with manufacturing small scale assemblies, where function takes priority over quality. As students continually repeat the manufacturing process, the quality of parts naturally improves. At Northern Michigan University, a repetitive process-based approach provides a model for teaching Mechanical Engineering Technology (MET) students the high quality manufacturing expectations required by industry, while at the same time, increasing motivation, and providing a service for organizations.

This paper will report the steps and curriculum design used to implement a repetitive process-based approach to teach MET students the design/manufacturing process Also, an overview of the final project required in the CNC sequence will be reported. The final project requires MET students to produce a specific number of assemblies for a community organization where all parts must pass quality standards. The high quality expectations at the end of the sequence creates a culture focused on quality of parts instead of students simply passing the class with a "C" grade. A culture focused on quality requires students to turn in "A" parts or not get credit for the project. This process trains students to strive for quality because the alternative is failure, thus, mirroring industry. This method has increased pass rates and competency and increased students interest in the topic, evidenced by time spent in the CNC lab without being required.

At Northern Michigan University, there is a capstone two-semester, "Senior Design" course sequence that all MET students must take. The first semester is dedicated to design and analysis, while the second semester is dedicated to build and test. The majority of the projects require some level of CNC machining to manufacture the product. This paper will highlight the effect repetitive process-based manufacturing has on the advancement of the quality of senior projects.

Introduction

Over the last decade the demand for graduates with both engineering and machining skills to fill manufacturing positions such as manufacturing engineers has increased. Many companies are looking to mechanical engineering technology students to fill the void [1]. In order for students to be prepared for manufacturing engineering, it is important the educational program simulates the manufacturing environment. Often silos exist within post-secondary education where students learn each individual skill within each course and only utilize the skill again if the course is a prerequisite for another or for the senior capstone project. At Northern Michigan University many courses are designed to break down silos and work across courses throughout the program to simulate industry. The intent being to have students go through the design to manufacturing process starting their freshman year and continuing to repeat the process as many times possible with increasing level of difficulty as the students' progress through the program. Thus, the term repetitive process-based approach is used to describe the repeat of the design and manufacture process. This describes the curricular philosophy within the manufacturing labs at Northern Michigan University. The intent of this paper is to report the process of implementing a repetitive process-based design to manufacturing system within an MET program. Also, the paper will report the motivation, interest, and competency increases observed over the last decade. This paper offers a perspective that has been successful at Northern Michigan University and took many years to implement.

In the early stages of teaching manufacturing to mechanical engineering students, it was difficult keeping students interested and motivated. As time went on it was the teaching strategies that changed the dynamics of the courses and increased motivation and interest. Teachers who develop challenging content where students can connect themselves to the outcomes influence attitudes in the positive direction [2], [3]. If teachers' have a student centered attitude toward learning as opposed to teacher centered instruction, the students' are more likely to develop positive attitudes, which leads to greater student interest [3]. Greater student interest is a predictor of performance [4], [5]. Teacher centered projects are typically single part projects assigned, programmed, machined, and lastly, graded by the professor. The problem with the typical method is the "A" through "F" grading structure used at most institutions. In industry, a "C" grade part does not pass quality control; however, in education, the "C" grade is passing. Standard grading creates a low stakes environment; which, encourages some students to produce average work for a low end passing grade. The average students then struggles when introduced to their first industry job where quality standards must be high. Also, teacher centered projects often exclude the learning of teamwork skills, creativity, and design skills necessary in industry.

The repetitive process-based approach naturally improves quality by forcing students to turn in parts that pass quality inspection. In order for a process-based approach to be successful in regards to quality, the project must be at the appropriate level of difficulty so students can be challenged yet successful. Creating projects above the capabilities of the students will create poor attitudes and frustration. On one project implemented within the department, the scope of the project was excessively large and demanded an unreasonable amount of time, the project had to be scaled back mid project. Extensive planning is required when planning a project to ensure all aspects of the project are possible. The considerations for project selection will be detailed in this paper.

The final two-semester capstone course is the most challenging design-to-manufacture project the students complete before graduation. The first semester is dedicated to design and analysis, while the second semester is dedicated to build and test. The majority of the projects require knowledge of their engineering courses and some level of CNC or manual machining to manufacture. This paper will highlight the effect repetitive process-based manufacturing has on the advancement of senior project quality.

To properly implement a design-to-manufacture process within an MET program it is necessary the school has sufficient lab equipment and the curriculum structure that allows for collaboration across courses. It is also important to note the increase in material usage because of the increased scrap from students making parts that don’t meet quality standards. A solution to the increased cost will be discussed. It should be noted, this is not a quantitative study. The reported results are based on observations, grades, course evaluations, and discussions with both students and employers. The following section highlights the lab equipment used at Northern Michigan University for the repetitive process-based approach.

Lab Equipment and Materials

Lab equipment, tooling, and materials are crucial when implementing repetitive design to a manufacturing curriculum. Equipment investment requires buy-in from the school and the department leadership. When the repetitive design-to-manufacturing process was first established, there was a shortage of equipment which created student frustration due to the time spent waiting for machines to manufacture parts. In the beginning stages of the program, the department had one Haas GT10 turning center, one Haas VF1 machining center, and several manual lathes and mills. To solve the equipment problem, the department worked with local industry and the university equipment fund to purchase additional equipment. The process to build the equipment inventory in the lab has been gradual throughout the ten years the program has been in place. The lab now consists of the following machining equipment, see Figures 1 & 2:

- Two Haas VF1 3-axis machining centers
- One Haas SL10 turning center
- Three Haas TL2 turning centers
- One Haas TL1 turning center
- Eight Haas control simulators
- Ten Clausing gear driven lathes with digital readouts
- Five Bridgeport vertical mills with digital readouts
- Two drill presses
- Three band saws
- One small CMM

Along with machining equipment, the lab is equipped with typical precision measuring equipment used in machining including several full sets of micrometers and calipers, gauge blocks, surface plates, dial indicators, and height gauges.

Figure 1. CNC Laboratory

Figure 2. Manual Machining Laboratory

When a quality focused project is assigned and only quality parts are accepted, materials become expensive. No longer are "C" grade parts accepted so students often re-make parts that do not pass quality inspection. It is necessary to find a solution to raw material sourcing such as, reaching out to local vendors, local manufacturers, and finding project sponsors to complete a specific project. The use of aluminum is preferred because it's fast to machine, easy on equipment, and tool life is longer. For projects where material other than aluminum is required, the lab can manufacture things to sell, or take on projects funded by outside sources. An example of a sponsored project were gauges designed and manufactured for the USA Luge Association officials. The Luge Association contacted the Engineering Technology Department with a request to manufacture gauges to check the sleds and equipment of the luge athletes prior to their runs. The gauges are now used as the official gauges at the Salt Lake City and Lake Placid luge tracks. The USA luge team also has a set of the gauges. The project was no cost to the department and the USA Luge Association received quality gauges for minimal cost. The project required students to work with a representative of the USA Luge Association, which was an excellent opportunity. Four years after the project was completed, members of the department are contacted by alumni to talk about the project and how great the experience was to produce for an organization such as the USA Olympic luge tracks.

Tooling cost for the CNC courses became a major problem when the course numbers and project scope increased. To solve the tooling cost, a relationship with a local medical device manufacturing company was developed. This company supplies scrap carbide tools to the lab for the current cost of carbide scrap. The hand-picked tools may be out spec to machine medical implants or medical tools often needing to hold tolerances of .0005", but are high quality titanium coated carbide tools perfectly capable of holding tolerances specified within student designs using the aluminum we have from donations. The advantage of this system is the zero cost to use end mills. Tools are purchased for scrap price, used, and sold for scrap price. The scrap tools are held until the price of scrap carbide is high so the proceeds can be used to fund other tooling such as inserts for shell mills and lathe tools. The current inventory of end mills will likely last over 10 years.

Identifying the equipment needs is important in the design and manufacture process, overcoming the need for new equipment was extensive work and continues to be an area of improvement. Although equipment upgrades are necessary to implement a design and manufacturing system, a thoughtful program design is necessary to utilize manufacturing equipment within an ABET accredited MET program. The next section will describe the current curriculum at Northern Michigan University. The current version allows students to focus on manufacturing while at the same time having a solid foundation in design and core mechanical engineering principles.

Program Design

The ABET accredited Mechanical Engineering Technology program at Northern Michigan University is a 126 credit program. The student must pick from five offered 14 credit concentrations. The concentrations include; CNC Technology, Mechanical Design, Mechatronics, Manufacturing, and Alternative Energies. The CNC Technology Concentration is one of the most popular among the students. The MET program has been continuously improved using an active advisory committee composed of approximately 20 industry leaders from industries across the Midwest. Each year the advisory committee meets for an entire day along with all members of the department. Several programs are the focus of the meeting where industry leaders assess our curriculum based on the changing needs of industry. The committee gives recommendations and the department makes changes based on recommendations. CNC certificate and associates degree programs are also offered at Northern Michigan University. These additional programs increase the utilization of the lab equipment. Over the last decade, the MET and CNC programs have had extensive revisions and employers seek out our graduates.

Graduates are sought out by employers because of the engineering knowledge along with hands-on experience programing and operating CNC equipment. Employers comment on the understanding our students have of concepts of design for manufacturing and the students' ability to communicate with all stakeholders within a facility. To better understand the layout of the MET program with the CNC concentration, the required courses are listed below. Of the credits within the program, 30 credits are university-required general education courses with the remaining credits being as follows:

Major Courses (32 credits)

MET 211 Mechanics-Statics
MET 213 Materials Science I
MET 216 Materials Science II
MET 310 Mechanics-Dynamics
MET 311 Strength of Materials
MET 320 Mechanical Design
MET 410 Applied Thermodynamics
MET 420 Fluid Mechanics
MET 431 Senior Project I
MET 432 Senior Project II

Other Required Courses (56 credits)

CH 105 Chemical Principles [satisfied through general education]
DD 100 Technical Drafting with Introduction to CAD
DD 202 Product Development and Design
DD 203 Industrial Drawing and Design
ET 110 Introduction to Electricity
ET 360 Process Control Systems
ET 410 Testing and Data Acquisition Techniques
MA 104 College Algebra and Trigonometry [satisfied through general education]
MA 171 Probability and Statistics [satisfied through general education]
MA 271 Calculus with Applications
MF 134 Manufacturing Process
PH 201 College Physics I [satisfied through general education]

PH 202 College Physics II [satisfied through general education]
TE 351 Humanity and Technology [satisfied through general education]

CNC Technology Concentration (14 credits)

DD 103 Geometric Dimensioning and Tolerancing
IT 420 Quality Control
MF 233 Numerical Control
MF 263 Advanced CNC Operations
Any DD, ET, IT, MET or MF prefix course or AD 111

The curriculum is essentially composed of three phases. Phase one being the introductory courses, phase two the foundational engineering courses, and finally phase three being the advanced and capstone courses. During the first phase, students' are introduced to the technology and math concepts used throughout the program. Specific to manufacturing and design, students take a Solidworks course to learn proper sketching, solid modeling, and basic design. The Solidworks course prepares students to use the software as a design and engineering tool in courses such as product development and design, mechanical design, CNC, and advanced CNC. Manufacturing processes is another freshman level course used in phase one to teach students chip removal equipment such as turning and milling. In manufacturing processes, students learn how to use milling machines, lathes, print reading, basic quality control, precision measuring equipment, basic G and M code programming, basic material properties, and design considerations. Students within the program quickly recognize within the first semester the link between design and manufacturing by manufacturing a product designed in the Solidworks course. This project will be detailed in the next section.

After completing phase one, the students then complete the foundational engineering courses including statics, mechanics, material science, and mechanical design. Along with the foundational engineering courses, students typically take concentration courses so they can concentrate on the upper level engineering courses during the last phase of the program. Within the second phase of the program another design/manufacturing collaboration is assigned where the advanced CNC operation course manufactures the designs of a project assigned in the mechanical design course. Again, the details of this project will be highlighted in the following section. Upon completion of the foundation courses the students are able to take thermodynamics, fluids, and senior project. Senior project is the third and final phase of the design and manufacture process within the program. A common theme throughout the course sequence is the focus on working with specific design parameters and repeating the design to manufacturing process as many times possible throughout the program. The following section will highlight the details for the repetitive-based design to manufacture process, specific projects used, and considerations for each project, student comments, and employer comments on program advancements.

Repetitive Process

The repetitive design to manufacturing process was implemented to improve quality, motivation, interest, and competency. The development of the repetitive process has been developed over the last 10 years. New ideas are continually tested and implemented or changed until the process works and the intended outcomes are achieved. Specific themes have emerged that help in selecting projects from the trial and error process of improving the curriculum. The emerging themes are the projects must be:

- connected to the students interests.
- useful.
- appropriately challenging.
- allow for independence on time to work.
- include cross curricular aspects to break silos.
- have design constraints or parameters to create boundaries on the scope of the project.

If all or most of the themes are considered for a project, students will generally enjoy the project and feel it was worthwhile. Projects must give students the experience of designing using technical skills while at the same time allowing for creativity and original ideas meaningful to their interests. Providing the students the opportunity to design and manufacture a useful product is essential for students early in the program. The product may be useful for professors, community members, other students, themselves, or anyone else that appreciates what the students have created. The most successful projects are those when the “customer” of a project presents the desired product and the students connect with the idea. As the leader of the project, it’s important to bring in customers that will inspire the students and have an interesting project. Whatever project is selected, the students must feel connected to the project in some way in order for their motivation to remain high. The better the connection the students have to a project, the better the outcome will be, thus reinforcing the idea that performance is connected to interest [6] [7].

Next, the project must be challenging for students while at the same time achievable. As experienced programmers and engineers, professors get excited when projects emerge in which the projects are challenging. Project leaders must understand what is challenging for a professor may not be achievable for students. As an example, a project assigned to students was to design a pneumatic fixture to use within a machining center that functioned using spare M codes. The design required students to have knowledge in electronics, pneumatics, advanced CNC code, and designing and machining complex fixture plates. The project was taken on due to the professor’s excitement of the challenge and was far too advanced for the students enrolled in the course. It is important to ask the question, “who is the project challenging for, the professor or the student?” If the project is challenging for the professor, the project is certainly too challenging for the students. The pneumatic fixture project required the professor to work late nights figuring out problems in order to teach the students what to do the next day. The project ended being teacher focused instead of the intent of being student focused.

As the leader of a design to manufacture process, it must be understood that scheduled labs will become work time for student groups that are at different stages of the process. Some students will finish early and some students will need more time. Professors must be okay with the chaos of every student group working independently, each at a different pace. It can be difficult to let go of the idea of students showing up for class, everyone completes the lab of the day, and the class is over. That model is easy from a professor's perspective which is why it is referred to as teacher centered learning. Using the repetitive process requires labs to be open during non-lab times and lab time is used to check the progress of the students and provide feedback on ideas. Strict deadlines are enforced but time spend on projects prior to deadlines is not assessed.

The repetitive design to manufacturing process begins during the first semester of the program. It is important to note not all students involved in a given project are involved in all aspects of the design and manufacturing processes. For example, during the first semester of the program, the students in the manufacturing processes class fabricate small trailers used to pull behind an ATV. The students build the trailers from a full working set of prints supplied by the CAD design course. The students in the CAD design course may be enrolled in both the manufacturing and design course; however, enrollment in both courses is not always synchronized. Each semester the students in the design course improve the design from the previous semester based on testing and manufacturing suggestions from students. From the design perspective, the trailer is a good introduction to design because nearly all students are familiar with the basic design of a trailer. The design must specify weld callouts, provide exploded views of connection joints and modeled assembly, and include a bill of materials using basic readily available materials.

Figure 3. Trailer Project

From a manufacturing perspective, the trailer provides a method to teach fixturing, proper bolted connections, proper welded connections, consideration of wheel and tongue alignment, print reading, and overall quality standards. The trailer fabrication project is completed at the end of the manufacturing course after the students learn to use the equipment necessary. Student feedback from the trailer project is extremely positive. Following are student comments from course evaluation question, “What did you like about this course.”

- I loved the trailer project and I’ve never built anything like that before. It’s cool to know I can use Solidworks to design something and I can build it.

- The trailer project was awesome.
- The trailer project was the highlight of my semester.
- The projects were fun.
- It was fun to actually build something.
- I loved the hands on experience we received in labs, Along with the knowledge from lectures that helped piece everything together.
- Learning to work with a team. I am usually a loner.

The next design to manufacturing project is in MF 233, the introductory CNC course. The students are required to come up with a project requiring each student to create a part that will be a piece of an overall assembly or set. The focus of the course is G and M code programming of turning and machining centers. The project uses the same repetitive process where students must design and model the parts in Solidworks, create working prints, write the G and M code, and cut a part that passes quality standards. The quality standards for this project is typically defined by the professor. This project does not involve another course; however, the projects are usually a service to the university or community. Examples of projects completed in this stage are fluid transfer valves for the university power plant, Baja car parts for the Baja club, and chess sets for the chess club. The semesters the students chose to make the chess sets, the students were required to set up machines for high volume runs so each student could take home a chess set. Most of the student evaluations in MF233 are positive concerning the project. Negative comments are typically concerning the lack of equipment. The increase of equipment over time has reduced the quantity of negative comments involving equipment. Below are comments from MF 233:

- It would be nice if there were more milling machines
- We need more equipment
- The chess set project was my favorite part of the class
- I like that each of us made a piece for a complete chess set
- I liked the freedom to use the lab any time I wanted during the day. I wanted to be there as much time as I could spare.
- I like the hands on experience in the lab, fun to see designs come to fruition.
- I liked the project system. It made everything you taught clear
- I really enjoyed the instructors approach in labs. It was fun!

Following MF 233 is the advanced CNC course called MF 263. This course introduces Mastercam and the Renishaw probing system on the machining centers. This course starts the first day with an assignment to manufacture an air engine that is due in three weeks. The purpose of the project to force students to learn the process of using CAM software and posting code to a machining and turning centers. At the end of the project, students test the air engine using a compressed air line within the lab. Using a tachometer, the students have a competition to see whose air engine will have the highest RPM. The students with the highest RPM gets extra credit for the project. Students are extremely excited about this project and talk to each other about who is going to win all throughout manufacturing of the engine. At the end of the project, students are able to take home the engine. When the department has alumni events, the alumni consistently report they still have the engine and comment about how much fun they had building and testing. The air engine project gets students prepared using Mastercam for the two other rigorous projects in the course.

The next project in MF 263 is a fixture project, every semester the project is different and selected based on the considerations from above. The USA Luge project was completed as the second project in MF 263. Although the USA Luge project was a highlight, the most notable project was the design and manufacturing of a sheet metal tool called the Tinknocker tool used to connect sheet metal ducting. A local entrepreneur contacted Invent@NMU which is a local center for helping entrepreneurs. Several students enrolled in MF263 were student employees for the center. The local entrepreneur who designed the tool was looking for local manufacturers to help redesign his project and complete an initial run of 100 units. None of the local manufacturers were interested in the project. The department chose to use the MF 263 to help re-design the product and manufacture the parts. One student who previously took MF 263 and was a student mechanical engineer at Invent@NMU and worked as the project lead. Students in the class were placed into team of four students. Each team was required to design and manufacture a fixture to manufacture 20 finished quality assemblies of the product. The product consisted of three parts all made from tool steel. Two of the parts were made on a machining center and one on a turning center.

Figure 4. Picture of Tinknocker Tool

The students commented on their enjoyment of the entrepreneur's frequent stops to the lab while they were machining fixtures and parts. In the end, 100 quality inspected products were given to the customer and the students experienced the design and manufacturing of a product that was sold upon delivery. The product rights have since been sold to a large tool manufacturer and the MF 263 course project is highlighted on the tool website. The student comments for the project were extremely positive. Several comments include:

- It was hard finding the time to complete the project and at times was exhausting but I like we got credit for the project. Good experience, thanks Cale.
- I can't believe we got it done! It was awesome to see the stack of parts when we were done.
- Great class!
- Keep up the good work Cale.

- I loved the freedom to come and go in the lab.
- I really enjoyed Cale, I had no real experience with manufacturing and he really helped me understand the importance of designing for manufacturability.

The third project in the MF 263 course is a collaboration with the MET 320 Mechanical Design course. The project is selected by the professors of both the engineering design course and the CNC course. The project has previously been small machine vises, toggle clamps, and for most of the recent years has been designing fixtures for the materials testing lab. Thus far this project has built tensile fixtures for heavy steel plate and seatbelts, fixtures for mass producing Charpy samples, and fixtures for producing tensile samples. The winning fixtures from the Charpy and tensile semester projects are used to produce Charpy and tensile samples for the material science I and material science II courses. This project requires students in the design course to design a product with specific size, material, and intent constraints. The design students work in teams of 2-4 and must create an initial model and set a meeting with the manufacturing team made up of 2-4 students enrolled in the MF 263 course. During the meeting the design students present the design and the CNC students are required to examine the design and offer constructive suggestions to improve the design for ease of manufacturing. The meeting accomplishes two things. First, it places the responsibility on the CNC student to look at the model and make decisions of manufacturability. Second, it helps the designer understand the considerations of machine capabilities. Many of the students in the design course have already taken the CNC course so they often come to the meeting with good designs; however, a second set of eyes from a manufacturing perspective always changes the design to some capacity. Once the designs are finalized, a working set of prints and models are sent to the student manufacturing teams which then produce the parts.

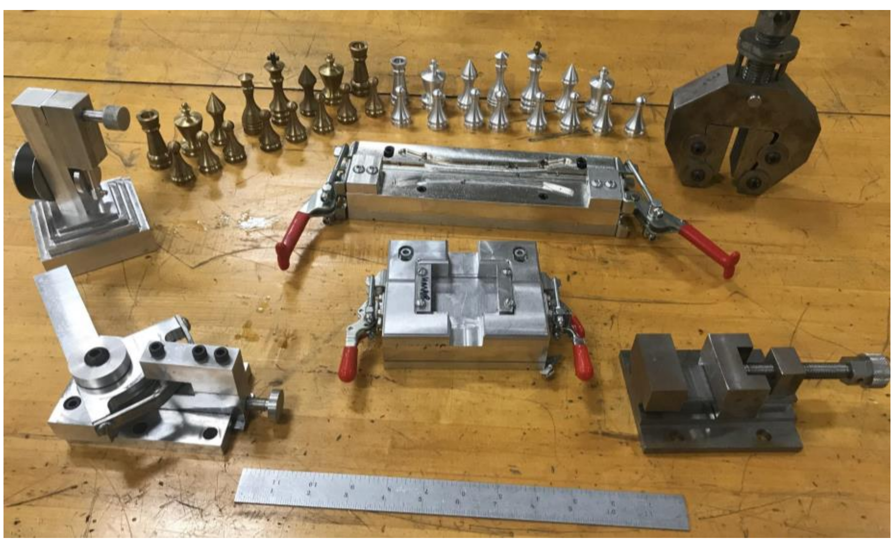

Figure 5. Air Engine, Chess Set, Toggle Clamp, Tensile Fixture, Vice, and Material Testing Sample Fixtures.

At the end of the project, the fixtures are tested using the testing values set by the design professor. The testing is done with both courses present and students are genuinely excited about testing event. This project is well known throughout the department and students typically love the collaboration between the two courses [8]. Students from both courses have positive comments concerning the project, examples are as follows:

- When your parts are being made by someone else, it helps to design good models.
- I loved seeing my parts get made
- I was nervous to screw up parts I was making for another student but it was fun testing when done
- I learned allot in this course
- I wish all courses were projects throughout the course
- After having to manufacture complex quality parts, I have a new perspective when I look at machined products.
- I'm ready to take on the world of machining!

The final stage of the design to manufacturing process is the capstone senior project. The capstone project is a two semester sequence with the first semester being the design phase and the second semester being the manufacturing phase. Students are given the opportunity to choose their own project as long as it meets the criteria of the department. If students cannot come up with a project, the department solicits ideas from the university, the community, or from companies. During the design phase, students model the initial design that includes material selection and manufacturing processes. Once the initial design is complete, Finite Element Analysis (FEA) is used to analyze the mechanical integrity of their design. At this stage, projects are changed based on the results and refined to a final design. At the end of the first semester, students are required to present their designs at a public venue where the audience is encouraged to ask questions and all people in attendance are given the opportunity to rate the engineering designs of the projects. Many students are nervous for the public venue and spend allot of time utilizing empty classrooms to prepare for the presentation.

The second semester of the capstone sequence is the manufacturing stage of the process. The students are required to work within the budget of the project. The students order materials, coordinate with vendors, and manufacture the design using the appropriate process. At this point in the program, students have access to all equipment within the department to manufacture their projects. When the projects are completed, they spend several weeks testing their project and are then required to present their completed project at another public venue. At this venue the engineering technology advisory board members are in attendance. Again, the audience is encouraged to ask questions and rate the project engineering and implementation. Students significantly improve their presenting performance from the first presentation.

Over the last decade the repetitive process-based approach has been developed, the senior capstone projects have become more rigorous and the design/manufacturing of the projects have drastically improved.

Conclusion

Repeating the design to manufacturing process improves students' motivation and interest while at the same time increasing competence and quality. As more design to manufacturing projects are implemented at Northern Michigan University, students have become more engaged, ask higher level questions, spend more time in labs, and student modeling and manufacturing skills have increased. The improvement of a project based system has also been beneficial to students and employers. The process of getting students to design using engineering concepts and having manufacturing skills takes years to implement and should be done at a controlled pace. If a school is looking at introducing more cross curricular projects, it is advised to start at the lower level and work through the problems that arise prior to starting another project in high level courses. Funding for projects and equipment is a consideration for all project implementation. One last benefit of breaking down the silos and working across the curriculum with other faculty is the comradery of working with colleagues and students on a common project.

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