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Project-based Learning in Manufacturing Processes Course

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Project based learning in Manufacturing Processes Course

Abstract

Integration of design and manufacturing is critical in producing successful products and systems. However, there are barriers between design and manufacturing related courses in engineering education. Manufacturing courses provide students with vast amount of technical information. They can only convert this information to knowledge if they use it in real life problems or projects. Most of the manufacturing courses cannot include such experience into their curriculum. An attempt to integrate design projects into a Manufacturing Processes course has been studied in this paper. Design projects are assigned to students and are expected to define their problem by determining possible combinations of materials and processes that could fabricate the desired shapes with the required properties. Students started with an existing part and redesigned it for predefined conditions. They also designed the manufacturing process and tools required to manufacture the part. They used several educational resources, CAD tools, and information provided during the lectures to design necessary tools to manufacture the final product.

1. Introduction

The "Four Pillars of Manufacturing Knowledge" [1,2] was designed to illustrate the full breadth of the manufacturing engineering field on one page and to be used as a tool for educators and industry professionals to describe the field. The manufacturing engineering education provides production related knowledge such as customer focus, quality and continuous improvement, manufacturing processes, product design, process design, laboratories, and many others. Four pillars are: (i) Materials and manufacturing processes: understanding the behavior and properties of materials as they are altered and influenced by processing in manufacturing; (ii) Product, tooling, and assembly engineering: understanding the design of products and the equipment, tooling, and environment necessary for their manufacture; (iii) Manufacturing systems and operations: understanding the creation of competitive advantage through manufacturing planning, strategy, and control; (iv) Manufacturing competitiveness: understanding the analysis, synthesis, and control of manufacturing operations using statistical methods, simulation, and information technology. ABET uses the same program criteria for accreditation[3].

Most of the industries will hire graduates with technical and professional skills. Therefore, the collaboration between industry and institutions is necessary[4]. Manufacturers advocate that educational institutions need to change their culture and behavior so more students complete programs of the study with real skills of value to industry, as assessed and represented by third-party industry-based certifications. By design, this will involve more targeted communication with industry, curriculum development geared toward employer needs, and stronger linkages to economic development[5]. The SME Certification Committee suggests knowledge categories for certification of manufacturing engineers and technologists. Two critical categories are (i) Manufacturing processes and (ii) Equipment and tool design. The academic infrastructure that is needed to educate and train a workforce with the knowledge and skills necessary to support manufacturing needs to be transformed and improved. Manufacturing Processes courses provide students with vast amount of technical information, but most schools have difficulty adding the necessary equipment and tool design experiences into their curriculum because of time and space limitations[6,7]. The integration of design and manufacturing experience into the undergraduate curriculum is not a new challenge[8,9]. Design and manufacturing integration in the curriculum has been usually done by including hands on project experience using Engineering Design course in junior level and Senior Projects[10]. However there has been always a barrier between design and manufacturing courses. An attempt to integrate design projects into the Manufacturing Processes course (MET1161) has been studied in this paper.

2. MET1161 Manufacturing Processes Course

At the University of Pittsburgh at Johnstown, Mechanical Engineering Technology students are required to take MET1161, Manufacturing Processes. This is typically taken during the junior year of their study by students in Mechanical Engineering Technology.

An overview of a variety of manufacturing processes is introduced that are available to process materials into finished products. Special emphasis is placed on the "traditional" processes from the standpoint of production methods, sequence of operations, and economic decision analysis.

The objectives of MET1161 include: (a) Provide each student with an opportunity to gain an understanding and appreciation of the breadth and depth of the field of manufacturing; (b) Emphasize and recognize the strong interrelationships between material properties and manufacturing processes; (c) Provide each student with an opportunity to become familiar with some of the basic metal cutting, forming, welding, casting, and polymer processes; (d) Provide each student with an opportunity to learn and apply the basic terminology associated with these fields.

Traditional lectures cover topics such as (a) Manufacturing systems and automation, (b) Manufacturing economics, (c) Casting and molding, (d) Forming processes, (e) Sheet metal forming, (f) Rapid prototyping, (g) Powder metallurgy, (h) Material removal processes, (i) Joining processes, (j) Measurements and quality assurance. Traditionally parametric manufacturing problems are assigned to students in manufacturing courses. They can easily solve well defined problems with the given input parameters and equations formulated just for a specific condition. However in the real world, technical problems are ill-defined and the real challenge is defining the problem that needs to be solved.

Some changes are made in MET1161 to improve students' skills in order to make them familiar with business-like working methods and real-life industrial practices. Project Based Learning (PBL) approach has been used to integrate design components into the Manufacturing Processes course. Project Based Learning is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to a complex question, problem, or challenge[11]. Learning objectives not only provide information and terminology about the manufacturing processes but also help improve their critical and creative thinking skills, oral and written communication skills, and teamwork skills by doing manufacturing related design projects[12]. When technical content is taught without application students forget it right after the final week and may decide to remember this content up later if they need it. When students have a project related problem that they are trying to solve, they actually want the knowledge and will use it immediately.

Real world problems are often open-ended, not fully defined and ill-structured, but student should handle such challenges[13]. Open-ended design projects provide a challenge to develop good judgment and confidence in their abilities as an engineer. PBL increases student retention rates and allow students to form useful connections between content of the course and problems expected to be encountered in their future careers in engineering.

In MET1161, three design projects related to (i) molding, (ii) forming, and (iii) machining processes were assigned. Students were also asked to write a technical paper and perform a presentation in the class. Students were free to choose their own product. They started their project with an existing product/part and they redesigned the part to improve it for the predefined conditions. Students also decided for the manufacturing process and tools required to manufacture the part. Sub steps were (i) describing the product/part, (ii) listing all parameters including assumptions/restrictions, and giving manufacturing related technical calculation results and information in form of technical drawings in the report.

In this PBL approach assessment of the projects is crucial. Assessment should provide students with the information they need to make their work better, through kind, helpful, specific, and timely feedback. Assessing teams' efforts during a timely project can be really overwhelming, especially in large classes. The key is to get the students involved, in peer and self-assessment. This allows the students to get much more high quality feedback than their teacher alone could provide. Steps followed in peer and self-assessment are (i) listing non-negotiable things that students must have in the project, (ii) looking at an example or case study together, (iii) brainstorming criteria, (iv) asking peer review after discussions. They were asked to report the minutes of their meetings as expected in real business settings.

3. Design projects in MET1161

In an attempt to achieve PBL, several design project assignments were implemented in the MET1161. Projects were related to sand casting and molding, forming, rapid prototyping, powder metallurgy, and material removal processes. One of the projects undertaken was an injection molded part. The first step in the project was to determine possible materials and processes that could be used to manufacture the defined part. This selection depends on predefined design criteria by the part selected and redesigned.

The second step was to design the manufacturing processes and tools required to produce the part. This was accomplished using Autodesk Inventor's mold library (Figure 1). The injection mold design process involves many steps that must be considered in a concurrent manner. As a result of this, many CAD systems[14,15] have developed CAD integrated computer aided manufacturing (CAM) systems for different manufacturing processes such as molding, forming, machining to help designers. Students learn useful skills by utilizing these systems in their project as today's manufacturing companies heavily depend on CAD/CAM systems and computers.

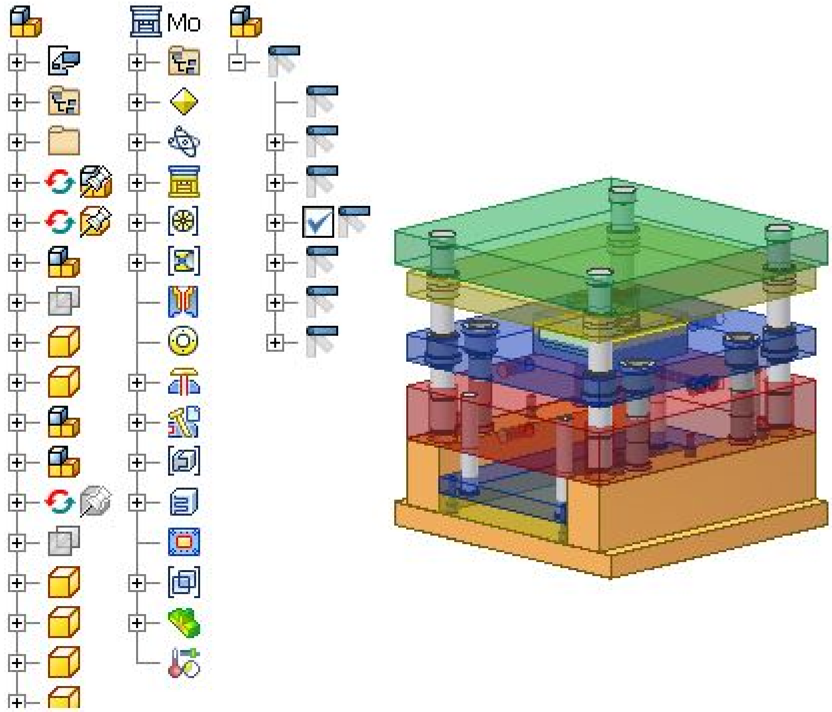

Figure 1 Inventor mold library overview

Steps to design molds in Inventor software are (i) create moldable parts, (ii) adjust the orientation and position of components placed in the mold, (iii) assign the material and its shrinkage value, (iv) generate the core and cavity for the moldable parts, (v) use patterning functionality to generate multiple components quickly in the mold assembly, (vi) define the runner system, the gates, and the mold base for the mold assembly (Figure 2). Simulations such as part fill analysis, runner balance analysis, clamp force calculations, mold kinematics can be easily performed with CAD system assistance.

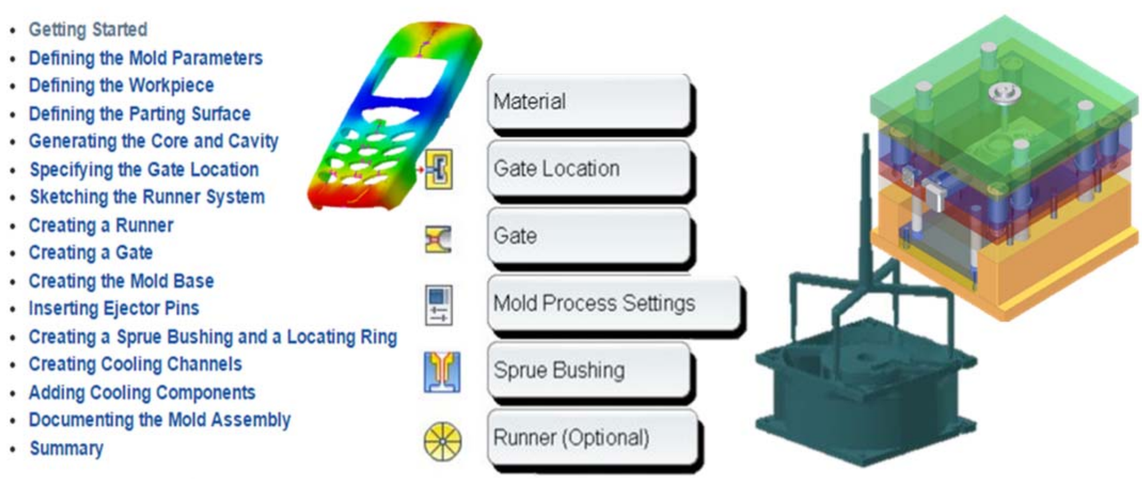

Figure 2 Mold design steps and simulations in Inventor

Students selected different parts to design. One of the student projects was to design IEC power receptacle (Figure 3

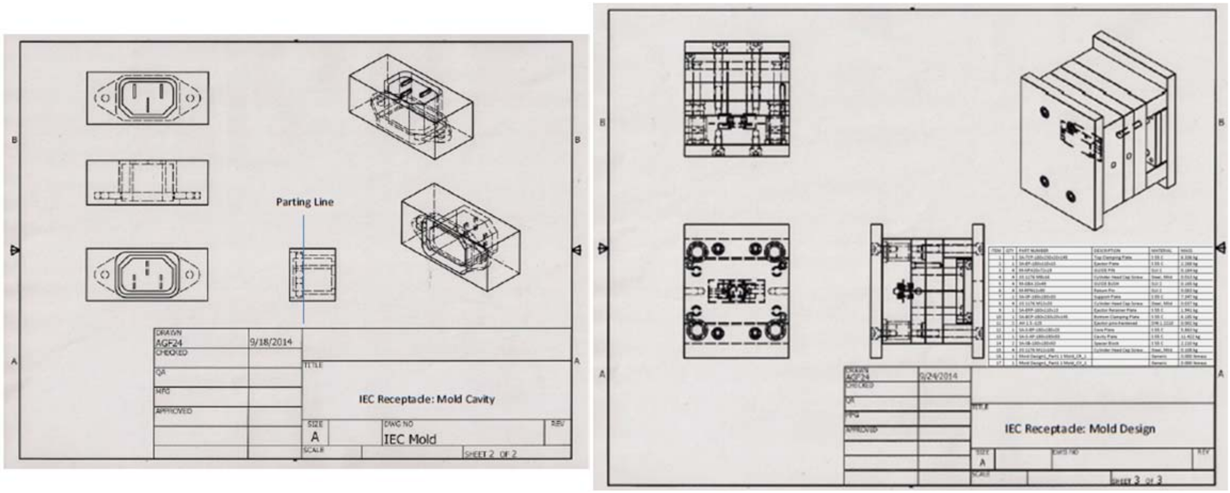

Figure 3). Mold and cavity have been designed after the process parameters are chosen based on material properties. Layout consists of symmetrical pattern of six work pieces and connected using a 3mm diameter runner. Plastic material will enter the mold cavity through two gates and follow the runner system to fill the cavity. The cavity is maintained at the set temperature so that the plastic can solidify in approximately 15 seconds after the mold is filled. The part will be removed by separating the mold at the parting line and with the assistance of ejector pins. After solid model of the work piece is created, it is used to generate the cavity in the mold. It is modified based on material shrinkage. The material selected for the IEC receptacle is a polycarbonate thermoplastic. It has a shrink rate of 0.007" per inch.

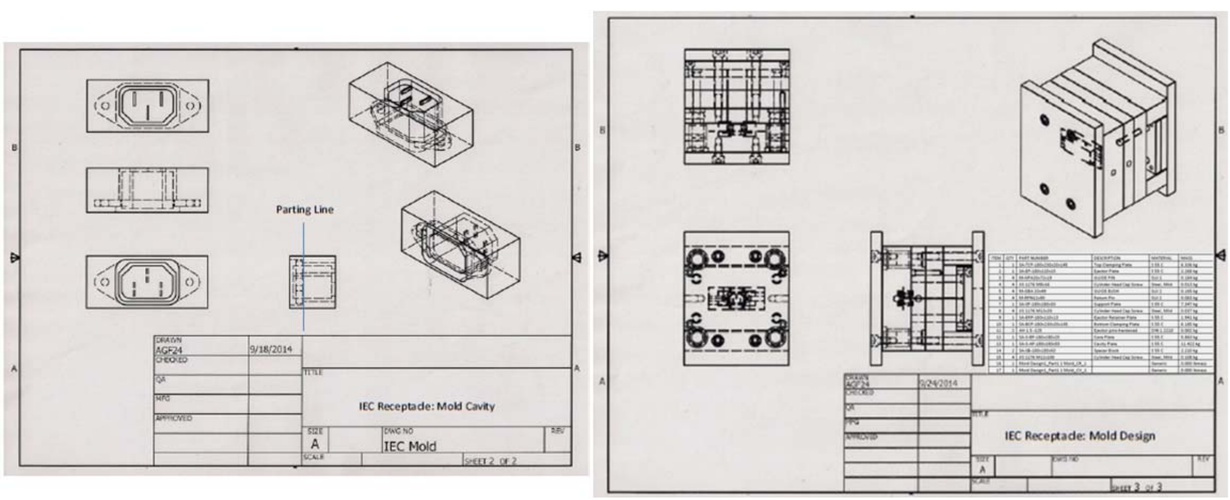

Figure 3 Mold design IEC power receptacle

4. Assessment of ABET or Program Objectives and Student Reflections

ABET or program specific criteria satisfied in MET1161 are: (a) ability to select and apply knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities; (b) ability to select and apply knowledge of mathematics, science engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies; (g) ability to communicate effectively. Design projects were successfully integrated into MET1161 using PBL approach and it helped students improve their skills by providing new knowledge, business-like working methods, and real-life industrial practices. Students benefited from the real-life projects. 63% of the students responded that they learned more with PBL compared to traditional lecture. They found the class discussions helpful, and were able to gain better understanding from explaining to and arguing issues with their group members. When asked "What aspects of this course were most beneficial to you?" in the survey (Figure 4), the response was as follows: "Design projects", "the projects given", "Dr. T. was easy accessible if needed.", "The projects that were needed to complete the course, was where a majority of my learning for the class came from. The projects made me apply what I learned in class more than trying to prepare for an exam.", "Engaging class discussions, case studies, and projects helped me understand material better.", "The projects are helpful in solidifying the topics we cover.", "good use of projects to help learn and test our understanding", "did a good job at trying to get us to think". Some students indicated that the seek for information to find the knowledge to solve the project related problem provided motivation for them to think and learn, not only for the sake of examinations. Those who did not enjoy PBL had stated similar reasons: "There was too much work involved in this approach, which reduces their time for other subjects". Students who felt that they learned more in lecture-based classes noted that it depends on a person's attitude and sense of responsibility.

4. COURSE COMMENTS

4.1) What aspects of this course were most beneficial to you?

- Design projects
- He did a good job at trying to get us to think
- Learning about manufacturing processes.
- The entire class was very beneficial and I learned a lot about manufacturing processes. The field trips in lab were the most beneficial part.
- The material. Also the method of teaching. Allowing us to use hand written notes on the exams almost forces us to take the notes. Writing everything down greatly enhanced the learning experience. This method can be used in other classes as well.
- The projects that were needed to complete the course, was where a majority of my learning for the class came from. The projects made me apply what I learned in class more than trying to prepare for an exam.
- learing the processes

Figure 4 End of Semester Student Survey

5. Conclusion

Integration of design projects into the Manufacturing Processes course (MET1161) using PBL approach is successfully mixing traditional lectures with some design based components. Adopting project based components in traditional lecture taught courses appeared to be the best way to satisfy industry needs without sacrificing knowledge of manufacturing engineering. Most of the industries hire graduates with technical and professional skills. PBL will help students improve these skills by providing new knowledge, business-like working methods, and real-life industrial practices. Students will benefit more from the real life situations in industry sponsored projects. However, it was observed that some students were not ready to be pushed directly into a project, and therefore when faced with the reality of unstructured and complex real-world projects they reacted in a non-constructive and potentially team-destructive way. Many students realize their future engineering role through this kind of projects. They benefited significantly and their improvement in learning and problem-solving skills was especially evident.

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References

[1] Society of Manufacturing Engineers, 2011, “Four Pillars of Manufacturing Knowledge“ available for download at www.sme.org/fourpillars], last accessed in February 2015.

[2] R.L. Mott and H. Jack (2013), “The Four Pillars of Manufacturing Knowledge Model – Illustrations of Mapping Curricula into the Model”ASEE Annual Conference.

[3] ABET, Inc., 2014, “Accreditation Standards and Program Criteria for Manufacturing Engineering and Similarly Named Programs.” Washington, D.C.: ABET, Inc., available for download at http://www.abet.org/eac-criteria-2014-2015/, last accessed in February 2015

[4] Hamid, M. H. M. I., Masrom, M., & Salim, K. R. (2014, April). Review of Learning Models for Production Based Education Training in Technical Education. In Teaching and Learning in Computing and Engineering (LaTiCE), 2014 International Conference on (pp. 206-211). IEEE.

[5] The Manufacturing Institute, December, 2012,“Roadmap for Manufacturing Education”, available for download at www.themanufacturinginstitute.org/News-Articles/2013/02/08-4-Year-Roadmap-Release.aspx, last accessed in February 2015

[6] Kadlowec, J., Bhatia, K., Chandrupatla, T. R., Chen, J. C., Constans, E., Hartman, H., & Zhang, H. (2007). Design integrated in the mechanical engineering curriculum: Assessment of the engineering clinics. Journal of Mechanical Design, 129(7), 682-691.

[7] Carlson, L. E., & Sullivan, J. F. (1999). Hands-on engineering: learning by doing in the integrated teaching and learning program. International Journal of Engineering Education, 15(1), 20-31.

[8] Lamancusa, J. S., Jorgensen, J. E., & Zayas-Castro, J. L. (1997). The learning factory—A new approach to integrating design and manufacturing into the engineering curriculum. Journal of Engineering Education, 86(2), 103-112.

[9] Carlson, L. E., & Sullivan, J. F. (1999). Hands-on engineering: learning by doing in the integrated teaching and learning program. International Journal of Engineering Education, 15(1), 20-31.

[10] Lewis, T. (2005). Coming to terms with engineering design as content. Journal of Technology Education, 16(2), 34.

[11] Donnelly, R., & Fitzmaurice, M. (2005). Collaborative project-based learning and problem-based learning in higher education: a consideration of tutor and student role in learner-focused strategies.

[12] Lamancusa, J. S. (2007). Design as the bridge between theory and practice. International Journal of Engineering Education, 22(3), 652.

[13] Wiek, A., Xiong, A., Brundiers, K., & van der Leeuw, S. (2014). Integrating problem-and project-based learning into sustainability programs: A case study on the School of Sustainability at Arizona State University. International Journal of Sustainability in Higher Education, 15(4), 431-449.

[14] Autodesk, Inc., “Tooling Tutorials: Mold Design”, Autodesk knowledge network, available for download at http://help.autodesk.com/view/INVNTOR/2014/ENU/, last accessed in February 2015.

[15] Dessault Systems, “Web Help Content Version: SOLIDWORKS 2015 SP02:Mold Design”, available for download at http://help.solidworks.com/2015/English/SolidWorks/sldworks/c_Mold_Design.htm, last accessed in February 2015