120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #6503

A Cross-course Design and Manufacturing Project

Dr. Michael Johnson, Texas A&M University

Dr. Michael D. Johnson is an assistant professor in the Department of Engineering Technology and Industrial Distribution at Texas A&M University. Prior to joining the faculty at Texas A&M, he was a senior product development engineer at the 3M Corporate Research Laboratory in St. Paul, Minnesota. He received his B.S. in mechanical engineering from Michigan State University and his S.M. and Ph.D. from the Massachusetts Institute of Technology. Dr. Johnson's research focuses on design tools; specifically, the cost modeling and analysis of product development and manufacturing systems; computer-aided design methodology; and engineering education. His work has been published in the International Journal of Production Economics, IEEE Transactions on Engineering Management and The Journal of Engineering Design.

Mr. Wm Adam Farmer, Texas A&M University

A Cross-course Design and Manufacturing Project

Abstract

In today's global and competitive environment, development of new products is a key aspect for firm success. New product development is a multidisciplinary process of systematically converting a concept for satisfying customer needs into a product or service that is ready for the market. Employers will be looking for graduates to have the skills necessary to join their product commercialization teams and contribute immediately. Students are also interested in learning relevant skills and participating in "hands-on" activities. This paper reports preliminary results from a project that has been developed to allow students to use the same "product" in three courses of a combined Manufacturing and Mechanical Engineering Technology program.

Background information on the involved courses and detailed aspects of the individual course projects is presented. Example projects and implementation experiences of the projects into the relevant courses are also summarized. The goal of the proposed projects is to highlight for students the relevance of each course and the applicability to future industrial applications. In addition, the project aims to convey the interrelated nature of courses in the curriculum. As such, pre and post intervention survey data related to student perceptions of overall course relevance and course interconnectedness are presented. Improved ratings are seen in some aspects of course relevance and integration. Suggestions for implementation in other programs and possible future work are also presented.

Introduction

In today's global and competitive environment, development of new products is a key aspect for every firm to thrive and achieve financial success. New product development is a multidisciplinary process of systematically converting a concept for satisfying customer needs into a product or service that is ready for the market. Employers will be looking for graduates to have the skills necessary to join their product commercialization teams and contribute immediately. Students are also interested in learning relevant skills and participating in "hands-on" activities. Providing students with high fidelity opportunities – those closely related to the types of problems they will see in industry – helps students develop the professional skills that employers are looking for in graduates.[1]

The ability to use CA-X tools (e.g., computer-aided manufacture or design) is becoming more important as CAD models become the nexus of the modern product commercialization environment. In addition to their initial purpose of creating detailed drawing for use in product manufacturing, these databases are now used for tooling fabrication, finite element simulations, and numerous other development process activities (e.g., packaging) [2]. CAD tools can be used by engineers located around the world to facilitate global development projects [3]. Project lifecycle management (PLM) systems allow engineers to access comprehensive libraries of historic CAD models and make changes to them. Demonstrating how this array of digital tools can be used in concert will allow students to develop professional and technical skills as well as demonstrate the industrial relevance and curricular coherence of their educational program.

The proposed project will allow students in three courses to develop and manufacture a product using the skills acquired in those courses. The work focuses on the use of CA-X tools to commercialize products. A combination of computer-aided design, engineering, and manufacturing tools are provided to the students for possible use throughout the project. This is representative of the industrial environment that students will enter, where these tools are pervasive. This work details the implementation of a cross-course project into three courses. A discussion of the project and the courses is provided in the next section. In the following section provides example projects and feedback data. The paper closes with a discussion of lessons learned and suggestions for implementation in other programs.

Course Integration

Course Descriptions

The exercises detailed in this work were implemented into three courses in a combined Manufacturing and Mechanical Engineering Technology program at Texas A&M University. The courses were all approximately junior level courses. The major content provided in the courses is shown in Figure 1.

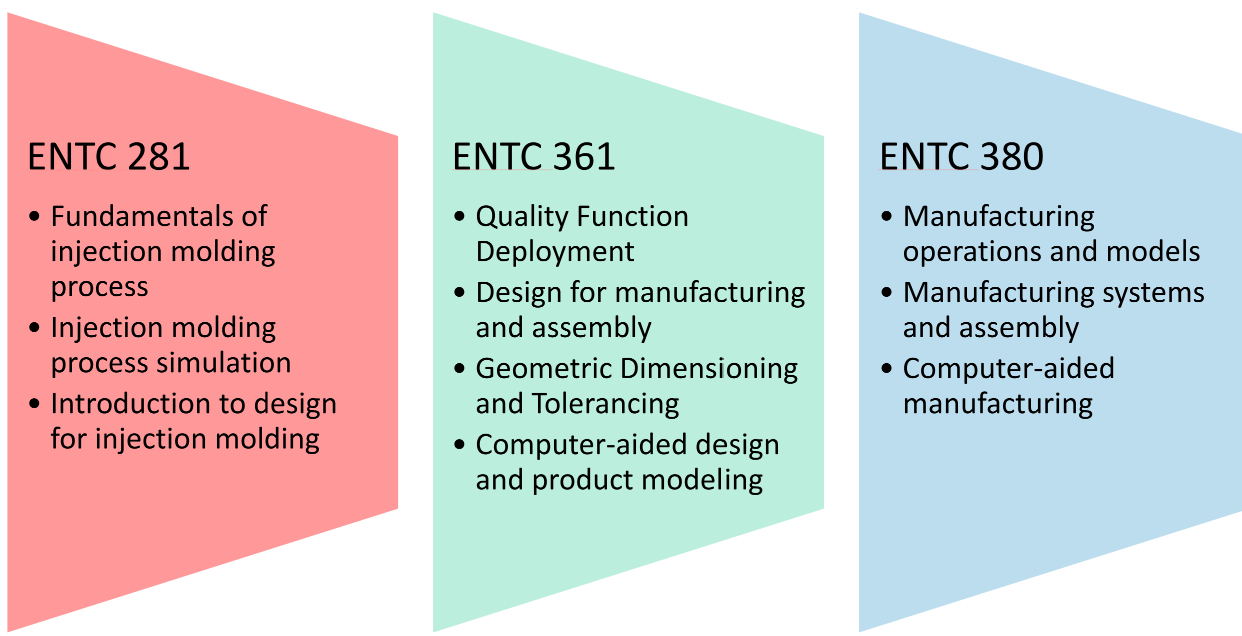


Figure 1. Included Course Content Overview

The first course is ENTC 281 Manufacturing and Assembly Processes II. In this course students are introduced to polymer manufacturing and assembly processes. The course has a laboratory component where students manufacture artifacts using the various processes discussed in lecture and examine the effects of materials and process parameters (e.g., injection pressure, temperature) on product attributes (e.g., quality, cycle time). In the injection molding laboratory exercise, students are introduced to injection molding simulation using the Autodesk Inventor Mold Design Tool. They examine processing conditions and gate locations for tensile specimens using the simulation software; they then manufacture and test these tension specimens[4].

The next course in the sequence is ENTC 361 Product Design and Solid Modeling. Students in this course are taught design processes and methodologies including: quality function deployment, materials selection, and design for manufacturing and assembly. Students are instructed in parametric computer-aided solid modeling during the laboratory portion of the course; this includes assemblies and creating detailed drawings. The Creo (Pro|Engineer) CAD software is used in the course.

The final course in the sequence is ENTC 380 Computer-aided Manufacturing. In this course students evaluate and analyze production systems, learn about automation technologies, and material handling technologies. In the laboratory portion of the course students learn the computer-aided manufacturing program FeatureCam. The end of semester project for this course currently entails students creating the required numerical code for the manufacture of an artifact of moderate complexity.

Evaluation and Exercise Descriptions

The exercises detailed in this work were implemented beginning in the fall of 2011. In the spring of 2011 baseline data regarding student perceptions of course integration, curricular fit, and general relevance were gathered. This was done using a survey instrument that was distributed in the three affected courses. The survey is shown in the appendix. The various alterations to the courses were implemented in the fall 2011, spring 2012, and fall 2012 semesters. Additional data (post intervention) was collected at the end of the fall 2012 semester.

Two new laboratory exercises were added to the ENTC 281 course. These exercises used the Mold Design Tool of the Autodesk Inventor Professional program. The first exercise provided students with a CAD model, a phone part from a Mold Design tutorial, and asked them to perform fill analyses with alternative materials, mold temperatures, and melt temperatures. The purpose of this exercise was to familiarize the students with injection molding simulation software and give them hands-on experience. This is in contrast with other work that focused only on demonstration of such software.[4] The second exercise that was implemented provided students with a process to create tooling from a CAD model of a given part. The parameters for the tooling were specified such that the component could be injection molded using the AB-400 injection molder that the students use during the course of the ENTC 281 laboratory. Students were given the choice of using a component provided by the instructor or one from the ENTC 361 course project. Students were incentivized with extra credit to use a component from the project. Students were provided a detailed plan to create the tooling layout; this included gate location, a runner, and a virtual sprue. Students were then asked to simulate the injection molding of their part with a given high density polyethylene. Students were also asked to suggest design and process modifications to improve the results of the molding simulation.

The next affected course was the ENTC 361 course. In this course homework assignments that were previously used to instruct students about the product commercialization process were adapted into a project. Students were asked to come up with concepts for a consumer product that contained at least three components that could be assembled. Students were allowed to use components off the shelf (COTS), but these did not count towards the minimum three components. Additional constraints were placed on the components as well. These included: that the parts be able to be injection molded using a straight pull mold (i.e., without any side actions or cores); the parts also had to be less than 14 grams and fit into a 70 mm by 50 mm by 15 mm envelope. These limitations were required to allow parts that could subsequently be molded using the AB-400 mold in the ENTC 281 course. Throughout the ENTC 361 course students evaluated the concepts, formulated customer inputs and functional requirements, created a cost model, and analyzed their product using design for manufacturing guidelines and Boothroyd et al design for assembly analyses.[5] Students were offered access to and assistance with the injection molding simulation tools detailed above to assist with their manufacturability analyses. Students created CAD models of their products using the PTC Creo (Pro|Engineer) software and composed a final report detailing and documenting their design process.

The final course affected by the cross-course project was the ENTC 380 course. Very little was altered structurally in this course. During the laboratory portion of this course students learn various aspects of the computer-aided manufacturing (CAM) software FeatureCam. The final project in the course requires students to prepare the computer numeric code (CNC) for a pen-holder of some other pre-defined product. The alteration in this course included allowing students to create tooling for a 361 project component in this course. The tooling CAD models are generated from the Mold Design program; students would prepare the CNC for tooling and manufacture it; they would then be able to create parts for their product using the AB-400 table top injection molding machine.

Results

Example Work

Over the course of two semesters students participated in the various affected courses. An example of the initial mold filling exercise in the ENTC 281 laboratory is shown in Figure 2. Students were shown the effects of gate location process parameters. The purpose of the first exercise was to familiarize the students with the Mold Design tool and introduce the effects of process parameters and gate location for use in the tooling fabrication laboratory exercise. Example output for the instructor provided part for that exercise is shown in Figure 3. In the fall 2012 semester, 7 students were concurrently enrolled in the two courses; of those, three used project parts for the laboratory exercise. Students were offered 5% extra credit on their ENTC 361 project or the equivalent in the ENTC 281 course.

An example of the type of project completed in the ENTC 361 course is shown in Figure 4; this is a key holder made of several assembled parts that would be screwed into a wall. Teams for this course typically consisted of four members. In the fall 2012 semester, one team (out of nine) documented the use of the Mold Design tool to assist in the manufacturability of their product. A fill analysis of a part from that group’s project is shown in Figure 5. Over the course of three semesters, no students have taken the opportunity to create tooling in lieu of their standard ENTC 380 project.

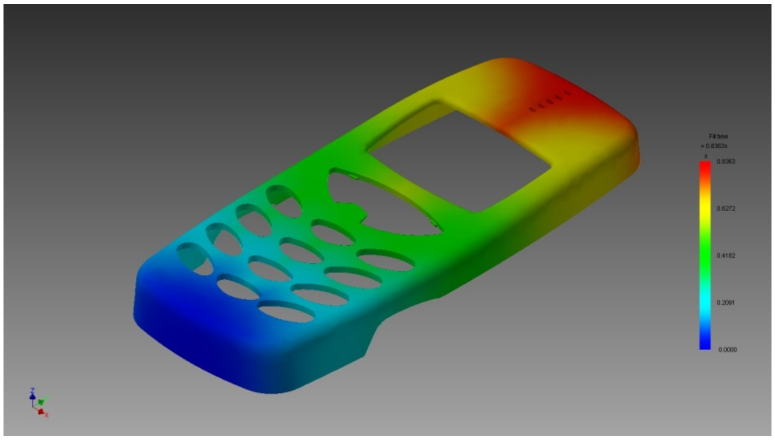
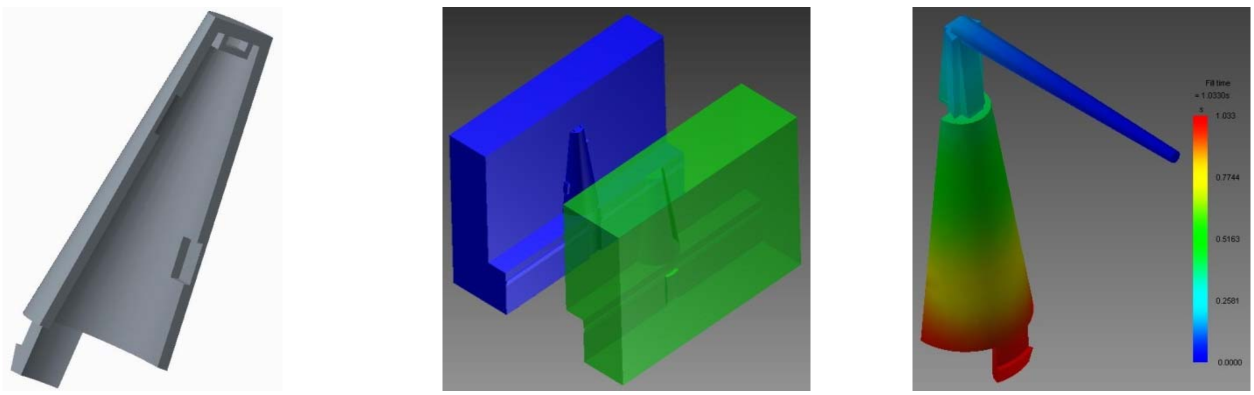


Figure 2. Autodesk Mold Design Tool Fill Simulation of Phone Cover



a. b. c.

Figure 3. (a). Instuctor Provided Part; (b). Cavity and Core Model; (c). Fill Simulation

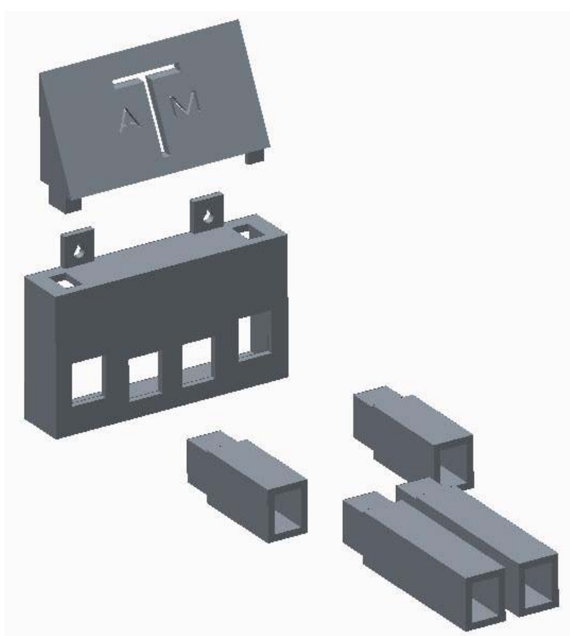


Figure 4. Example ENTC 361 Course Project: A Key Holder

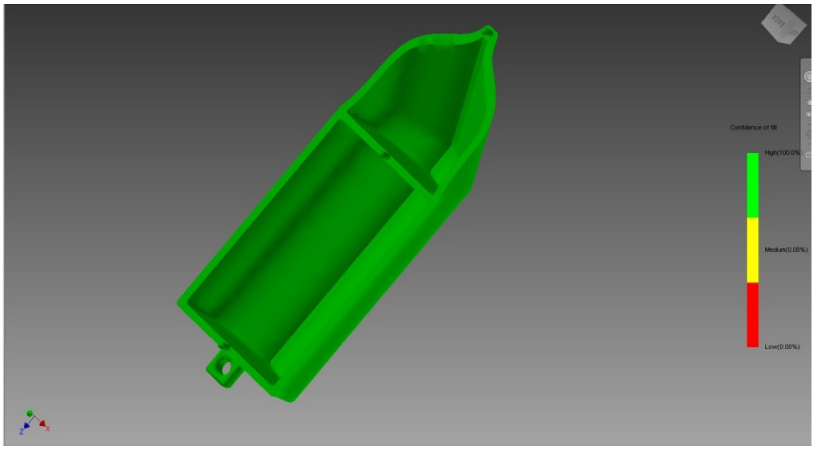


Figure 5. Mold Design Fill Simulation for a ENTC 361 Project Component

Survey Data

Data were collected from students pre and post intervention to assess the perceived effect of the course alterations on three main specific aspects: the relevance of the course to the students future industrial career, the coherence of the course with the overall program curriculum and interactions with the other two courses under consideration. Initial data were collected in the spring semester of 2011 prior to any course alteration. The post intervention data were collected during the fall semester of 2012. In both cases, data were collected near the end of the semester after students had completed the majority of course content. Table 1 shows t-test results for pre and post data regarding course relevance and curricular fit. While relevance increased slightly for the 281 course, curricular fit decreased slightly; neither change was statistically significant. The increases for both relevance and curricular fit for the 361 course were both statistically significant. In the case of the 380 course, the relevance ratings experienced a statistically significant decrease while the curricular fit rating received a non-statistically significant small decrease.

Table. 1 Total Pre and Post Intervention Student Feedback Regarding Course Relevance and Curricular Fit

	Test	Group	N	Mean	T-Value	P-Value
281 Relevance	Pre > Post	Pre	86	6.47	-0.583	0.561
		Post	81	6.53		
281 Curriculum	Pre > Post	Pre	84	6.48	0.733	0.465
		Post	79	6.37		
361 Relevance	Pre > Post	Pre	54	**6.11**	**-3.259**	**0.002**
		Post	36	**6.78**		
361 Curriculum	Pre > Post	Pre	54	**6.07**	**-3.116**	**0.002**
		Post	36	**6.69**		
380 Relevance	Pre > Post	Pre	70	**6.09**	**1.797**	**0.075**
		Post	68	**5.71**		
380 Curriculum	Pre > Post	Pre	70	5.91	0.077	0.689
		Post	68	5.90		

To assess course integration and see if the results differed among students that had taken all three courses, data for only students that had completed all three courses were analyzed separately and are shown in Table. 2. The relevance and curricular fit for the 281 course both increased slightly, however neither change was statistically significant. The integration between the 281 and 361 courses increased slightly, but was not statistically significant. The integration between the 281 and 380 courses decreased slightly, but also did not represent a statistically significant difference. For the 361 course, the sub-population results were similar to the overall data results for course relevance and curricular fit; both showed statistically significant post intervention increases. The course integration results for the 361 course with the 281 and 380 courses showed small post intervention increases, but these were not statistically significant. For the 380 course, the overall relevance and integration with the 281 course showed small post intervention decreases that were not statically significant. The 361 integration and curricular fit ratings showed small post intervention increases, but these were also not statistically significant.

Table. 2. Sub-population Pre and Post Intervention Student Feedback Regarding Course Relevance, Integration, and Curricular Fit.

	Test	**Group**	**N**	**Mean**	**T-Value**	**P-Value**
281 Relevance	Pre > Post	Pre	45	6.33	-0.276	0.783
		Post	31	6.39		
281 & 361 Integration (281)	Pre > Post	Pre	45	5.98	-0.080	0.936
		Post	30	6.00		
281 & 380 Integration (281)	Pre > Post	Pre	45	4.96	0.788	0.433
		Post	30	4.70		
281 Curriculum	Pre > Post	Pre	45	6.40	-0.307	0.760
		Post	31	6.45		
361 Relevance	Pre > Post	Pre	45	**6.33**	**-2.586**	**0.012**
		Post	30	**6.80**		
361& 281 Integration (361)	Pre > Post	Pre	45	6.16	-0.179	0.858
		Post	30	6.20		
361 & 380 Integration (361)	Pre > Post	Pre	45	5.27	-0.202	0.841
		Post	30	5.33		
361 Curriculum	Pre > Post	Pre	45	**6.29**	**-2.312**	**0.024**
		Post	30	**6.70**		
380 Relevance	Pre > Post	Pre	45	5.87	0.694	0.490
		Post	29	5.66		
380 & 281 Integration (380)	Pre > Post	Pre	45	4.96	0.506	0.614
		Post	29	4.79		
380 & 361 Integration (380)	Pre > Post	Pre	45	5.31	-0.674	0.503
		Post	29	5.52		
380 Curriculum	Pre > Post	Pre	45	5.67	-0.827	0.411
		Post	29	5.93		

Discussion

This work examined the effect of a cross-course project on student perceptions of course relevance, curricular fit, and course integration. A product design project was introduced in a junior level design course that allowed students to carry aspects of the work into other courses. These courses included a polymer manufacturing course and a computer-aided manufacturing course. The inclusion of the project in the product design course led to statistically significant increases in student perceptions of the course's relevance and curricular fit. There were also small, but not statically significant, increases in the perceived integration between this course and the other two courses. Two new laboratory exercises were introduced into the polymer manufacturing course. These exercises did not have any statically significant effects on the overall perceptions of relevance, curricular fit, or course integration. Only a handful of students took the opportunity to evaluate parts related to their design project in these laboratory exercises. Finally, students were given the opportunity to replace an existing end of the semester laboratory project in the computer-aided manufacturing course with the creation of tooling related to the project. Over the semesters analyzed, no students took advantage of this opportunity. There were no statistically significant effects noted after the provision of this opportunity with respect to course relevance, curricular fit, or course integration.

While the inclusion of the project had a significant effect on the perception of one course (361), it did not dramatically affect the other courses. One reason for this could be the scale of the intervention in the various courses. In the 361 course, the project represented a significant portion of the students' grade (15% of the overall course grade); the project also ran the course of the entire semester. In the case of the 281 course, the intervention represented two lab sessions (the equivalent of approximately 4% of the overall grade) over two weeks. In the 380 course, the intervention represented a small option associated with a small portion of the course. Another issue with the integration of the project is the order in which a number of students take the courses. Most students take the 380 course concurrently with the 281 course and before the 361 course. This reduces the ability of students to use the 361 course project in a forward going manner. Another possible problem is the level of incentive for students. A "canned" exercise is likely to be easier due to peer help and more readily available resources than a custom exercise based on a project. To mitigate some of these problems and further promote the integration problem two suggestions are proposed: 1) advising should be used to have students take the product design course earlier in the curriculum (there are no prerequisite impediments to this); 2) incentives (e.g., extra credit) should be increased to incentivize students to use their project content in these other courses.

References

[1] Shuman, L.J., Besterfield-Sacre, M. & Mcgourty, J., (2005). The abet "professional skills" — can they be taught? Can they be assessed? *Journal of Engineering Education*, 94 (1), 41-55.

[2] Field, D.A., (2004). Education and training for cad in the auto industry. *Computer-Aided Design*, 36 (14), 1431-1437.
[3] Eppinger, S.D. & Chitkara, A.R., (2006). The new practice of global product development. *MIT Sloan Management Review*, 47 (4), 22-30.
[4] Johnson, M.D., Diwakaran, R.P. & Zsiros, J., (2010). Conveying the importance of manufacturing process design using simulation results and empirical data. *ASEE Annual Conference and Exposition, Conference Proceedings*. Louisville, KY, 2010-996.
[5] Boothroyd, G., Dewhurst, P. & Knight, W., (2002). *Product design for manufacture and assembly* Boca Raton, FL: CRC Press.

Appendix

I have or am taking the following courses (check those that apply)

ENTC 380____
ENTC 361____
ENTC 281____

Please circle your answer for the following questions; for those that apply to classes you have not taken please circle NA (not applicable). 7 – corresponds to a positive rating; 1 – corresponds to a negative rating.

ENTC 281

I found the content of ENTC 281 relevant and see how it could be used in industry.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I see the connections between ENTC 281 and ENTC 361 and understand how the information in learned in these two courses can be used together.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I see the connections between ENTC 281 and ENTC 380 and understand how the information in learned in these two courses can be used together.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I understand how ENTC 281 fits in the MMET curriculum and understand why this is a required course.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

ENTC 361

I found the content of ENTC 361 relevant and see how it could be used in industry.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I see the connections between ENTC 361 and ENTC 281 and understand how the information in learned in these two courses can be used together.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I see the connections between ENTC 361 and ENTC 380 and understand how the information in learned in these two courses can be used together.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I understand how ENTC 361 fits in the MMET curriculum and understand why this is a required course.
Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

ENTC 380

I found the content of ENTC 380 relevant and see how it could be used in industry.

Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I see the connections between ENTC 380 and ENTC 281 and understand how the information in learned in these two courses can be used together.

Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I see the connections between ENTC 380 and ENTC 361 and understand how the information in learned in these two courses can be used together.

Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

I understand how ENTC 380 fits in the MMET curriculum and understand why this is a required course.

Strongly Disagree 1 2 3 4 5 6 7 NA Strongly Agree

Optional Comments: