

Leveraging Automatic Identification and Data Capture in an Undergraduate Engineering Technology Capstone Course

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Students pursuing a degree in Engineering Technology and Management at Ohio University are required to complete a manufacturing based capstone course during their senior year. This capstone course provides the students with an authentic manufacturing experience where they are responsible for designing, developing and leading a group of their peers to manufacture finished goods in a production environment. Students must also fulfill the requirement to develop and deploy a database driven inventory management system with a web interface to track the movement of raw materials, work in process and finished goods inventories. Additionally, the students must build mechanisms to capture the measurements of key part characteristics, part failures and the causes of the failures. The students must be able to develop appropriate reporting and use these reports during their production run to mitigate product failures. The complementary course competencies from previous courses in the curriculum that provide the scaffolding for the students to be able to build the capstone inventory management system are identified and the requirements of the inventory control system are discussed.

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The Capstone Experience at Ohio University

The capstone course within the engineering technology and management department at Ohio University exists as a comprehensive manufacturing experience. While the lectures for the course provide a foundation in operations management, the students are required to leverage the competencies they have achieved in past courses to design a product as well as the required engineering and manufacturing documentation. The students are also required to build production tooling, work instructions and conduct pilot builds which lead to a production run. During their production run, the students will manage a group of their peers who will build one product for each student enrolled in their section of the course, plus one product that the department keeps as reference for future capstone groups. The production run duration is six hours, and the students typically build between fourteen and twenty-one products.

The intent of the capstone course is to provide guidelines for a project with requirements that must be met but minimal use of templates and structured procedural instructions. The students are provided with reference material via past capstone classes. These documents provide a general reference, but in many cases the students may not be able to use the documents as templates because of the different context between the projects.

The course exists as a problem based learning (PBL) environment, and as such it focuses on the five primary characteristics of such an environment: Problem-focused, student-centered, self-directed, self-reflective and having a facilitator instructor². This environment is intentional to allow the students to synthesize what is actually required within the context of their project. Schwering³ supports this methodology and defines the act of providing an open-ended project based project as one of the hallmarks of a superior capstone experience.

Project Requirements

Students enrolled in the capstone course divided into groups of four or five students. The class typically has between four and six of these groups. The students are responsible for purchasing the raw material for the products that they will be building. The products that they design do have a few design constraints. They must be comprised of more than seven fabricated (not purchased) parts. The products must have at least one moving part, such as a door or drawer. Example products include a mantle clock, a diploma display case and a dart board case.

Fabricated parts are parts that start as a raw material, usually a rectangular piece of wood. These raw material parts are required to be processed into the desired geometry through the manufacturing processes as

defined by the students who are managing the production run. The students who are managing the production run are the ones who designed the products, tooling, and work instructions, but they are not able to perform any of the actions required to transform the raw material into the finished good. The other students enrolled in the class are used as workers for the production run. The workers rely on provided documentation, training and mentorship from the supervising group. The tooling, work instructions and process documentation are expected to be written clearly such that a person could use their raw materials to build a finished product without asking any questions and without any external reference. The ability of the class to produce the products under the supervision of their peers is dependent upon robust documentation, tooling and training.

Combined and Expected Educational Outcomes

The Engineering Technology and Management Department validates that the curriculum is current and relevant through review by an advisory board comprised of outstanding business executives, many of who are graduates of the department. This group works with the faculty to ensure that the curriculum is current and relevant and that the department is continuously producing graduates who fulfill the guidelines of the program.

During the capstone experience, the students are expected to execute against many of the competencies from many of the courses within the curriculum. While the students are enrolled in the Engineering Technology and Management program, the students take a minimum of 9 credit hours (3 courses) completing core applied computer based technology courses. These required courses are called Enterprise Computer Methods, Applications of Object Oriented Programming and Database Applications and Analytics. While the students pursue competencies within those courses (defined in the following three sections), they are required to recall and apply the competencies from these courses within their capstone experience to accomplish the task of inventory control.

The faculty collaborated to develop the requirement of the students to implement an inventory control system within the capstone course. This component of the class is not only a critical portion of the production experience, but it also assesses many of the competencies that have been targeted through several courses.

The infusion of the inventory control system into the capstone experience provides an authentic learning experience consistent with the strategies of providing open-ended requirements which the students must leverage the competencies from other courses to develop a solution to the problem³. The students are required to design, build, test and implement a technological solution

to solve some of the challenges they will face during their production run.

Enterprise Computer Methods

The Enterprise Computer Methods course ensures that students have an appropriate basic technological foundation through providing an exposure to common methods of data manipulation as well as an overview of how databases work. Selected course competencies include:

1. Generate plots and charts using spreadsheet software.
2. Use database software to generate tables, relationships, keys, queries, and forms.
3. Use data base software to sort, filter, and analyze data
4. Interface data base software with other business applications to import and export data, create mailing labels, and generate form letters

Applications of Object Oriented Programming

The Applications of Object Oriented Programming course is designed to expose the students to basic programming while also providing the opportunity to apply these skills through several projects. Course competencies include:

1. Create C# applications using the integrated development environment (IDE)
2. Compose windows form applications using objects which include text boxes, message boxes, dialog boxes, labels, controls, menus, frames, picture boxes, pull-down menus, and combo boxes
3. Define and modify the properties and methods associated with an object
4. Create variables, constants, relational operators, logical operators and Visual C# data types
5. Design control structures using the if-then, if-then-else and if-then-else if statements
6. Manipulate strings using various String functions
7. Design repetitive control structures (loops) using while, do-while and for Loops
8. Add multiple forms to a project and create classes that contain multiple methods
9. Use one dimensional arrays and timers in your applications
10. Create windows applications that read from and write to sequential text files
11. Debug windows application using the Visual Studio debugging environment
12. Display a database table in a DataGridView control and write applications that display, sort and update database data
13. Create user defined class objects, methods and properties

Database Applications and Analytics:

The Database Applications and Analytics course provides an applied experience for the students to expand database exposure in the Enterprise Computer Methods course. The students are required to design and develop several different databases and database types as well as executing several projects to combine the skills that they have gained. Students are required to interface their databases with a website as well as developing reporting methods to provide appropriate analytics. Selected course competencies are listed:

1. Design and Create database tables in Access and Microsoft SQL
2. Design and Create one-one, one-many and many-to-many relationships between tables using Access and Microsoft SQL
3. Identify and develop various Database Management System (DBMS)
4. Manipulate a database using SQL to retrieve, store, modify, delete, insert and update data
5. Design and Create custom forms in Access, Windows C# and ASP websites
6. Design and Create custom reports in Access, Excel, Windows C# and ASP websites
7. Import and Export data between Excel, Access, and Microsoft SQL server using Windows C#

Inventory Control Requirements

Because the intent of the course is to provide an educational experience that simulates a manufacturing environment, the students are required to leverage automatic identification and data capture (AIDC) techniques to develop their inventory control strategy, build and implement the software. Inventory control strategies such as this are very common in modern manufacturing environments¹.

The students are required to leverage barcodes and barcode scanners during their production run on their parts as a modern method of capturing parts for their inventory control purposes. AIDC methodologies are utilized to increase efficiency to enter part numbers into the inventory database and to reduce the incidence of mistakes caused by individuals mistyping part identifiers, typically part numbers, into the inventory control system. These are typical applications AIDC systems within industrial settings¹.

Students are provided with a prepopulated framework to help them start developing their inventory system. They also receive several sessions with a mentor, as well as a sample demonstration of a previous solution developed by students. A simple sample database and a basic website to be used as the interface are provided as part of this framework, as well as a barcode scanner. Students are also provided with a description of the

requirements for the inventory management system. They are encouraged to use each other and the faculty as resources to develop their solution.

Requirements are defined such that the students must control their inventory at several key places within their production run. The students are provided an inventory staging area, and they are required to track their raw material as it is released from this inventory into the production environment. Work in process (WIP) inventory is also tracked with their inventory control system as well as their finished goods. The inventory control system that the students design, build and implement is required to be able to track each of their parts from inventory, through WIP and as built into a finished good. This is a basic but typical inventory workflow⁴.

To be able to provide complete traceability of their parts across the manufacturing environment, the students must also provide a mechanism to track defective parts. Typically during a production run, several parts will have defects. The students must be able to accommodate the defects either through scrapping the part (discarding it) or bringing it into compliance through rework (unplanned corrective actions). However, the students must be able to provide a report at any time concerning the exact location of each part.

The defective part reports are particularly helpful for the students who are executing the production run. Key quality characteristics can be captured and charted against passing parts to allow the students to be able to predict if their process is going out of control before they are actually creating poor parts using control charting methodologies⁴.

Students are required to provide the class with a working demonstration of their solution before their production run. This gives the class opportunities to review the solution, try to break it and provide input towards improvement. The students typically have at least one week to incorporate the suggestions of their peers and professors into the final working version of their inventory control solution.

Future Opportunities

The Engineering Technology and Management students acquire many diverse skills through the successful completion of many competencies within the program. Because the capstone course currently exists as one five credit hour course taken during one semester, the course is very compressed with respect to the deliverables expected of the students. Several students expressed frustration that they wanted to pursue more within the course to push their projects further but were constrained by time. There may exist opportunities to split the course into a two semester experience where the student focus

on the Operation Management portion of the class and the second class focuses on their production run.

By spreading the course over two semesters, the students would have more time to develop a more robust inventory control system that may be able to offer more advanced features such as a real-time dashboard or a production scoreboard. Both of these are common within production environments⁴.

One additional opportunity would be for the students to further extend the functionality of their inventory control system through a requirement to build the system in a way that backflushes (removes) raw material and parts from WIP when a product is scanned into finished goods. The intent of this extension of the system would be to replicate the typical functionality of a traditional ERP system. This interaction would provide a deeper level of assessment of the student competencies related to inventory control, parts handling and systems integration within the modern manufacturing environment.

References

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