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CHARACTERISTICS OF AN INDUSTRIAL TECHNOLOGY CAPSTONE COURSE

CLAYTON RAY DIEZ, DAVID N. YEARWOOD, LUKE H. HUANG
University of North Dakota

Introduction

An undergraduate program may normally provide students with about 40 courses in the process of preparing them for training towards a profession. While these courses are spread out in different fields, it is often a challenge for students to effectively maximize the application of knowledge learned from theses course to carry out a professional project. Yet, it is precisely what is expected of graduates. On the other hand, after several years of taking classes, many seniors become tired of listening to lectures, as reported by the Carnegie Foundation for the Advancement of Teaching.[1] Can something be done to address these existing problems?

The Carnegie Foundation report, "Reinventing Undergraduate Education: A Blueprint for America's Research Universities" suggested—following a study of undergraduate education—that students' education should "culminate with a capstone experience."[1] In this report, it was suggested that the final semester of an undergraduate study focus on a major project utilizing to the fullest what students learned in the previous semesters. To promote this proposal, The Carnegie Foundation, joined by the Association of American Colleges and Universities (AAC&U), launched a national project, “Integrative Learning: Opportunities to Connect” on November 17, 2003.[2] Among 140 applicants, ten universities were selected to develop and assess advanced learning models that fostered students’ abilities to integrate their leaning. The outcomes of the project are expected in 2006. Further, although adopting capstone courses is believed to add value to undergraduate study a need exists to correctly identify the benefits of this course. Moore [3] listed 13 advantages of having capstone courses, which can be divided into three categories: 1) enriching the senior-year study; 2) perfecting the implementation of the program mission; and 3) being employed as an assessment tool. Whereas the first two directly put impacts on the program through integration of all previous course work, the latter reflects a role that other course cannot offer—assessment of the total program. This role has been practically studied and performed in certain specific undergraduate programs and was proved to be quite successful.[4]

A pilot test of a mini project was conducted prior to full implementation of the capstone course. The information learned from this activity was then integrated, on a much larger scale, into the three-credit capstone course. The result of which was to allow students the opportunity to integrate what they have learned into practice by starting and operating a simulated, or in some case, an actual, viable business. Based on the uniqueness of the approach by the faculty in the department and the desire to continuously improve the quality of education, the designed capstone curriculum must have the following three distinctive characteristics:

1. That the curriculum ensures integration of all major courses in the program in the capstone course.

2. The design of the course project must provide opportunities for students to uncover and integrate the necessary elements for starting and maintaining a viable business.
3. That the capstone course be employed as a powerful tool to assess the effectiveness of course work in the program thus providing opportunities for continuous improvement of the Industrial Technology program.

Identification of Content

An analysis was conducted of the Industrial Technology program course objectives to identify content required for the capstone course. During this analysis it was determined that the capstone course should include a review of relevant concepts within each program area as a refresher for students enrolled in this course. The items that were identified included technical and managerial concepts from the major emphasis areas within the Industrial Technology program. It was also thought that due to the nature of the required projects in the capstone course, students would also need a refresher in the basic business fundamentals necessary to ensure effective operation of the simulated company. The final part of the course was the coordination of a student initiated and operated enterprise that designed, produced, sold, and distributed a viable product.

Course Description

The capstone course is designed to integrate course work covered throughout the students' experience at UND, specifically those within the IT program. Several elements–reflective of the structure of most manufacturing businesses, have been identified to provide students with experiences akin to a 'real world' scenario. These are as follows: strategic planning; product design and manufacturing; production planning, and distribution strategies; and quality processes and assessment schemes all of which are addressed by course work within the department. Students will work collaboratively to create an environment that incorporates various elements of their technical expertise to produce an end product that is commercially viable.

Course Format

The format of the course was designed for faculty to serve as facilitators for the class. The initial meeting was set up to assist students in assigning project teams and initiating the strategic planning process. Once the teams were set, faculty from the Technology Department provide a review of concepts integral to the technical and technical management components of the course and guest lecturers from the College of Business & Public Administration provide an overview of the business concepts that industrial technologists need to understand as they work together as team to market a successful product. The faculty members serve as external consultants to the team(s) as the course evolved. Teams then set to work on their respective projects and met with the course coordinator on a schedule basis to: report progress, for troubleshooting, to review portfolios, and conduct assessment activities scheduled for the course—progress on reports and formal presentation. The culminating assessment activities were the presentation of the technical reports and oral presentations during the week of finals.

Course Objectives

The overall objective of the capstone course is multifaceted in scope and requires students to demonstrate skills and competencies in many areas addressed in the major. Students accomplish this through the completion of a complex project that will showcase their ability to transfer knowledge and skills acquired from the course work in some meaningful and tangible way. A significant aspect of their work on this project requires that students approach problems/challenges encountered in a manner that may be similar to the way they are handled by those in the profession.

The specific course objectives for the capstone course were determined by thinking of them in terms of what we wished our students to be able to do–intended learner outcomes. Huba and Freed[7] suggest soliciting the aid of various professional entities to ensure relevance, authenticity and validity of these outcomes, something we found relatively easy to do given the department's close ties to industry. Three groups provided the Technology department with input related to learner outcomes. These were: professional associations–National Association of Industrial Technologist (NAIT), the program's accrediting body, the program's Advisory Council consisting of past graduates employed in various industrial/technological fields, and other field professional. A primary reason for proceeding in this manner was to ensure credibility of the learning outcomes and the matching of skills/competencies consistent with industry thus ensuring their usefulness to the profession. The course objectives are listed below and are stated in terms of what students show know and be able to do.

Students will learn how to:

- Develop a strategic plan for applying research strategies/methodologies to develop a product from an idea to one that is salable
- Work as contributing members of a team/group in planning, coordinating activities which require the application of organizational, managerial, fiscal,

promotional, and manufacturing concepts typically found in an industrial or business setting

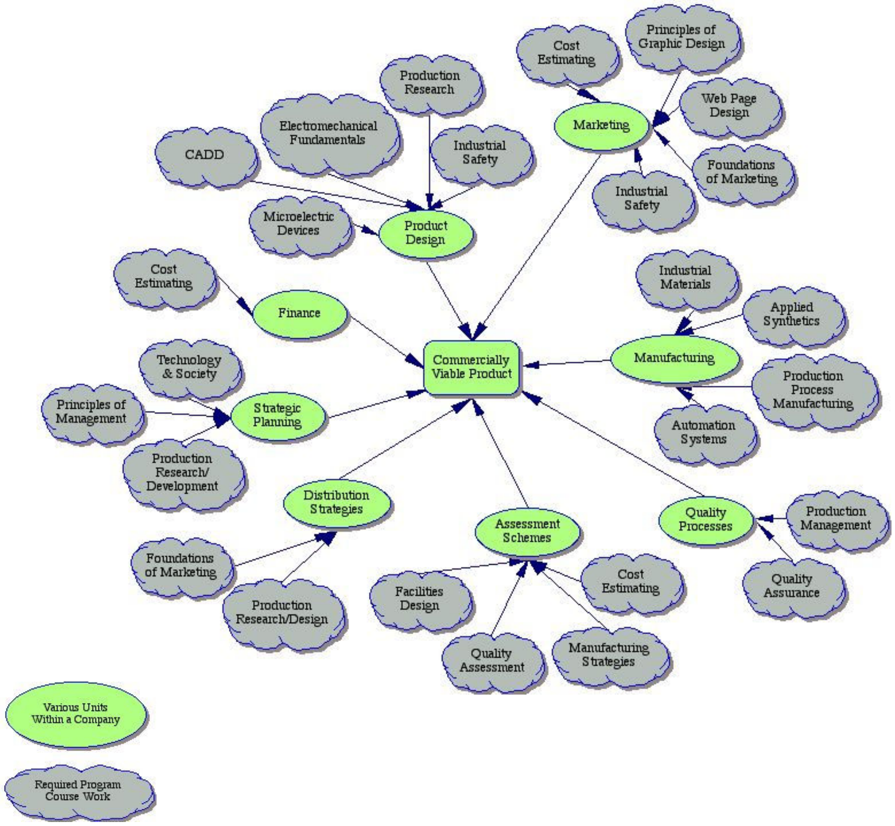
- Supervise the production planning, control, and quality aspects of the manufacturing process to complete their project.

Content Selection Process

The capstone course is designed around the integral cornerstone of an Industrial Technology program of study and integrates important aspects of business disciplines. A technical manager must have basic knowledge and application/problem solving skills that revolve around the technological components of society in addition to the managerial and business background to ensure that the business/industry is productive and profitable. Additionally, the capstone course is organized to draw from the course work required of students in the program and allow them to work as a team to "put the parts" together in one course and simulate how a company would initiate a new product and see it through from ideation to distribution and sales. The primary objective of this approach is to allow student to experience the steps involved from the business side of a company and those required of the manufacturing side of the company.

The integral course concepts are mapped in Figure 1. These are comprised of units that allow students to work in a team atmosphere to initiate various elements of the projects. The purposes were for students to gain experience in how to design and develop a product, strategically plan, finance, assess and manage, produce, ensure quality, market, and distribute a product.

Figure 1 – Various Units of the Capstone Course



As indicated in figure 1 of the Concept Map demonstrates how the basic core concepts are developed individually, then integrated into more comprehensive units that contribute to a holistic coordinated simulation of how a company functions in creating a commercially viable product. Each unit—product design, manufacturing, etc. – is connected to program required industrial technology or related professional course work. Basic core concepts identified from program courses as specific objectives are addressed as part of the integration into the capstone course structure. For example, industrial technology courses required for the product design component include: Computer-aided design drafting, product research and development, technical drawing, electromechanical fundamentals, electronic circuits and devices, industrial safety, and manufacturing strategies are required courses that contribute specific objectives related to Product Design. Using Manufacturing as a second example one can see that courses such as: production processes: manufacturing, applied synthetics, industrial materials, principles of graphic design and print production, manufacturing strategies, and industrial safety are invaluable elements of that unit. Each unit is linked to courses for basic core knowledge required of a practicing industrial technologist.

Assessment of the Capstone Course

Assessment of student academic achievement is important because it can provide information about program goals, revision of curriculum, clarification of program objectives, and the meeting of accrediting standards. The systematic evaluation of student achievement focuses on educational learning objectives and the use of these results for continuous improvement are key elements of assessment, which according to P. Way (personal communications, October 2001) are both formative and summative.

The multiple measures of assessment utilized for the capstone course were made-up of two fundamental aspects of student learning: direct measures of learning–project completion, exhibition, and oral examinations; and indirect measures of learning–observations and informal conversations from unannounced visits by faculty, including self report surveys or interviews relative to students' perceptions about the effectiveness of the capstone course. Measurement of goals and objectives must reflect the missions of the department, college and university. Additionally, the goals measured should provide a cross-section of the learning objective domain (P. Way, October 2001, personal communications). The assessment measures were those selected for determining achievement of learning outcomes. The checklist as shown in Table 1 were used to determine the success in each of the three outcomes areas.

Table 1

Learning Outcomes Achievement Checklist

Outcome	Exceeds	Meets	Below
Strategic Planning			
Product Identification			
Brainstorming			
Refinement			
Testing and Evaluation (Analysis)			
Decision-making			
Implementation			
Organization, Planning, and Control			
Organization Chart			
Event Scheduling			
PERT Chart			
Bill of Materials			
Flow Process			
Motion and Time			
Assembly			
CADD Drawings			
Quality Assurance/Analysis			
Jig and Fixture Design			
Cutting Processes			
Routing			
Sanding			
Assembly			
Finishing			

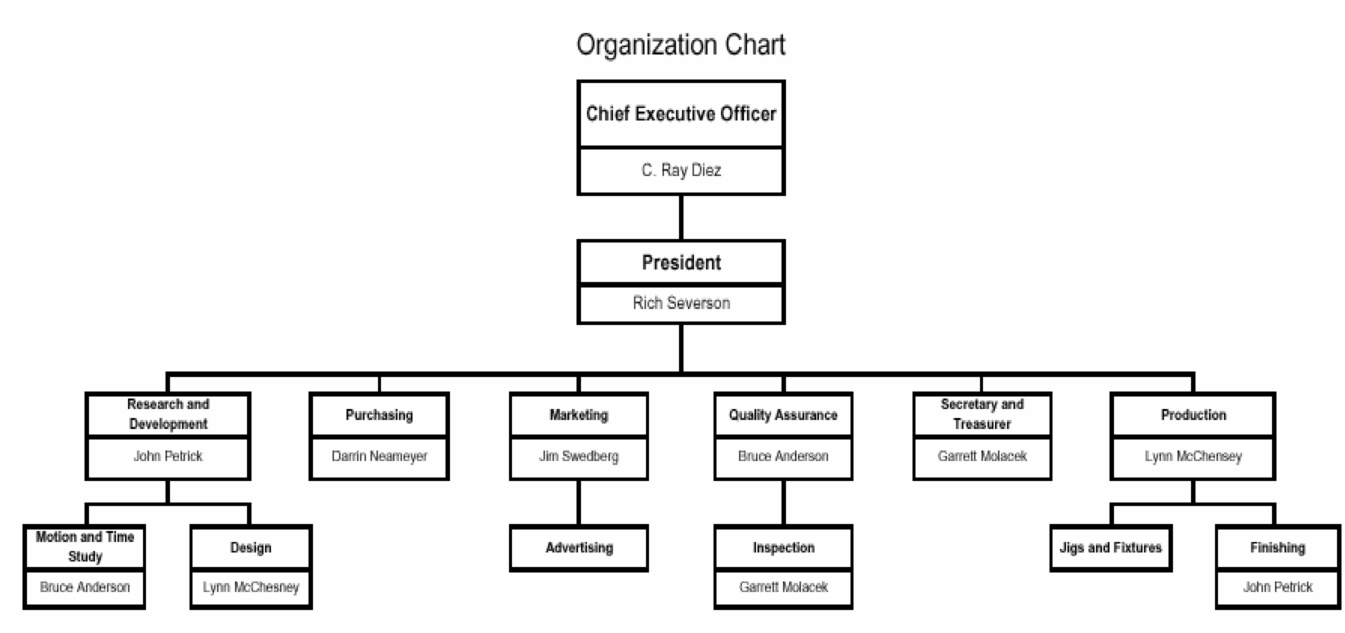
Direct assessment—summative assessment—of student learning involved the completion of a project–from design through testing, to manufacturing. The completed project is then put on display where it is evaluated by professionals in the field as well as faculty with expertise in area of the students' work. Students are also evaluated orally on aspects of their project. This is done during the presentation of their work to a panel of experts–faculty and field professionals–who in turn ask questions relating to several aspects of the students' work. These questions run the gamut from cost–profit ratio; funding sources, and market feasibility of the project; use of materials in the design, testing and building phases; operational characteristics; manufacturing, etc.

Mini-project Example:

The "Clockworks" project was used for the pilot test. This project was designed to determine its effectiveness as a possible capstone project used to assess outcomes of an industrial technology program of study. The goal was to produce a commercially viable product that was profitable to the simulated enterprise. The process is summarized in the following paragraphs.

A seven-person team operated as an enterprise to produce a product that simulated the steps from organizing an enterprise, initiating a new product line sales, conducting a marketing survey, planning for production and quality control through sales and distribution of the product. The team selected the company name of "Clockworks". The organizational structure included a Chief Executive Officer (CEO), a president, six departments and sub-departments covering the required operations.

Figure 2 Organizational Chart



Responsibilities were devised as follows:

- CEO directed the overall project.
- president was responsible for day-to-day functions of the enterprise.
- department heads were the leaders for the respective project activities.
- departments were divided to assume operations according to expertise.
- team members were assigned as department employees.

The departments functioned as teams with leadership rotated to ensure all team members had the opportunity to experience the various roles in an organization. The departments were also organized to mirror those found in the organizational structure of an enterprise. The structure allowed students to experience a variety of responsibilities required in an enterprise. The departments and sub-divisions were:

- Research and Development: Responsibilities included time and motion study and product design.

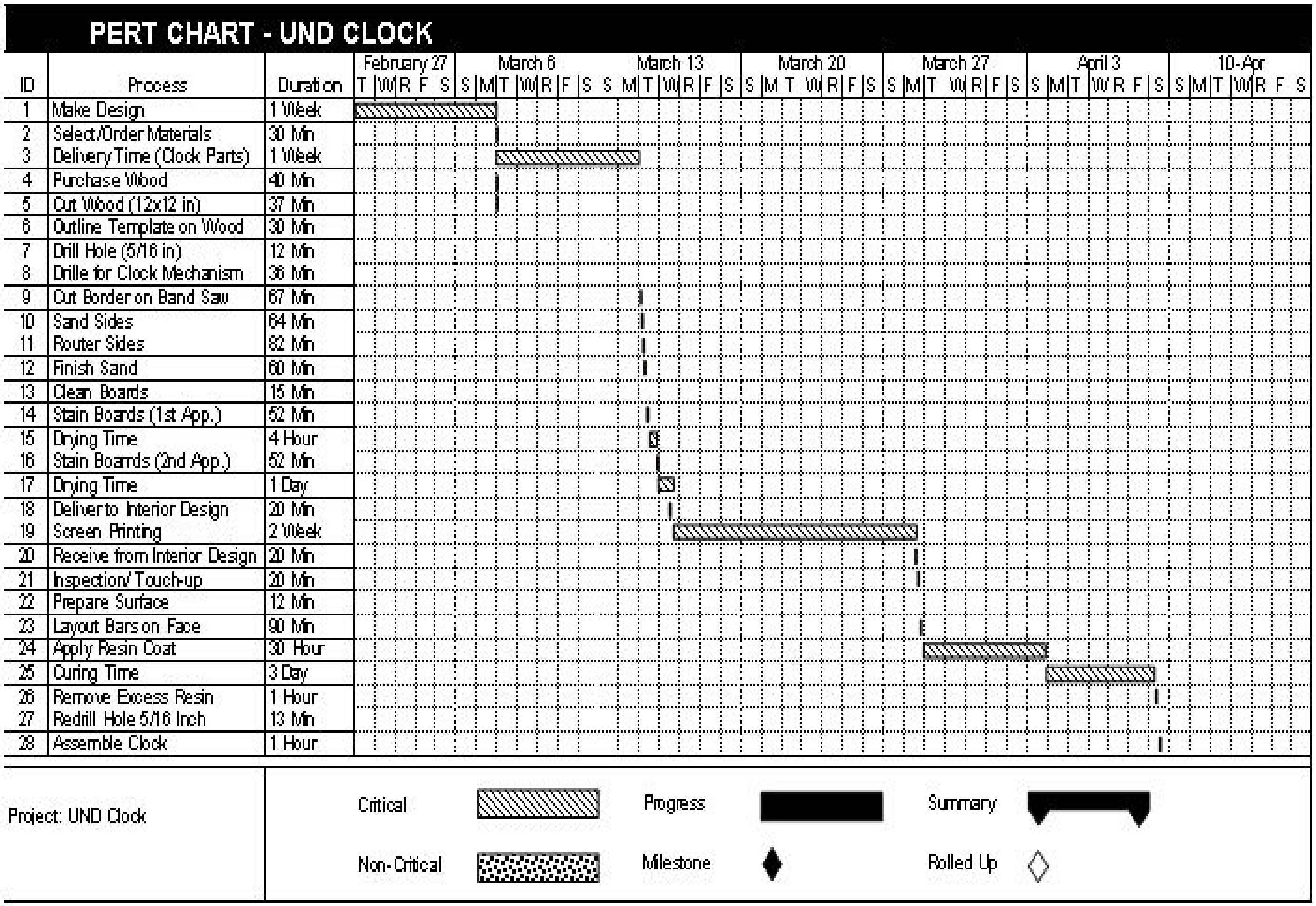
- Purchasing: Development of cost estimates, bills of materials, and procurement of needed supplies were major components.
- Marketing: Pre-market and pre-production surveys, advertising, sales, and distribution were coordinated in this department.
- Quality Assurance: Overall quality checks, in-process and post-process inspections of the products were completed.
- Secretary/Treasurer: All financial and economic functions of the company were controlled through this department.
- Process: Production organization, planning, and control were the primary focuses of this department. Examples of activities included preparing jigs and fixtures and directing the finishing process.

Company and department meetings were held to build team infrastructure; develop a strategic plan; brainstorm; determine product criteria; determine the final design; develop the planning, organization, and controlling functions; identify and conduct required marketing; determine the financial operations structure; set standards for quality assurance; and ensure that procurement would be carried out in a timely fashion.

One example of the brainstorming and associated processes was the product selection and decision process. Twelve initial preliminary designs were trimmed to two during product identification. Pre-market surveys were conducted, prototypes were analyzed against design criteria, and the final product design was selected using a variety of decision-making strategies.

Strategic planning was conducted to identify the organization, planning, and control for the production process. The processes were identified, flow charts, PERT

Figure 3 PERT Chart



charts, a critical path method chart, and a step-by-step process chart were developed. An interrupted circular flow process layout design

Figure 4

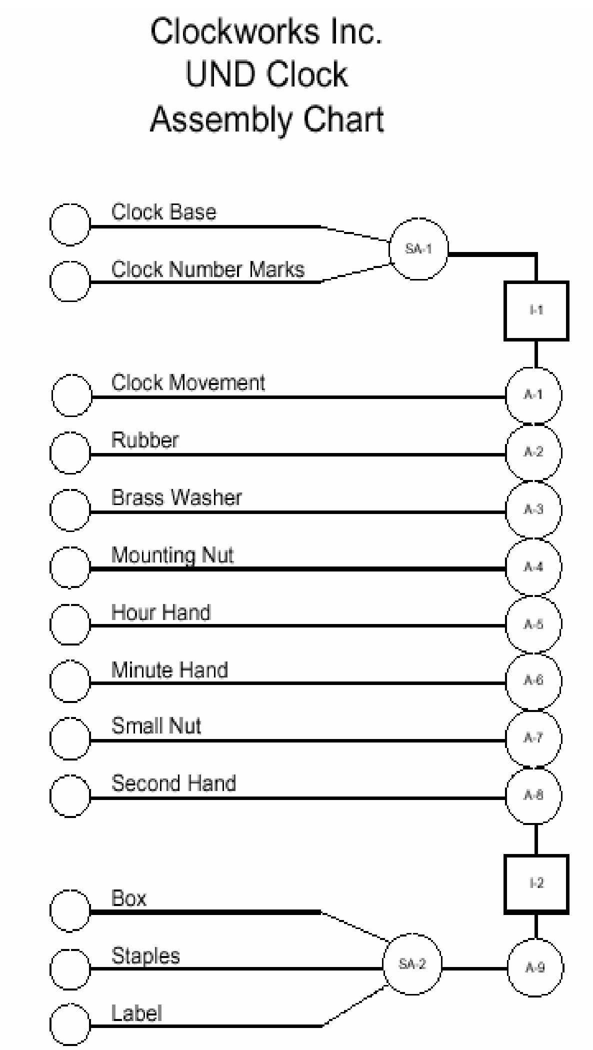
FLOW PROCESS CHART

PART NAME Clock
PROCESS DESCRIPTION Job Shop
DEPARTMENT Industrial Technology - IT 403
PLANT Clock Works
RECORDED BY Administration

STEPS	OPERATION	TRANSPORT	INSPECTION	DELAYS	STORAGES	DETAILS OF METHOD	DISTANCE IN FEET	TIME (MINUTES)	
1		●				Receive Materials	—	3	
2	●					Mark off 12" sections	—	1.25	
3		●				Move materials to radial arm saw	10	.25	
4	●					Cut wood into 12" x 12" sections	—	1	
5		●				Move to template station	10	.25	
6	●					Outline template on wood	—	.1	
7		●				Move to first drill press	15	.5	
8	●					Drill hole through	—	1.2	
9		●				Move to band saw	15	.5	
10	●					Cut border	—	22	
11		●				Move to belt sander	10	.25	
12	●					Sand with belt sander	—	2.15	
13		●				Move to hand router	8	.25	
14	●					Router the sides	—	2.5	
15		●				Move to second drill press	8	.25	
16	●					Drill with forstner bit	—	1	
17		●				Move to sanding station	6	.2	
18	●					Sand boards	—	2	
19			●			Inspection	8	3	
20	●					Rework bad boards	—	.5	
21		●				Move to cleaning	—	.5	
22	●					Clean boards	—	.25	
23		●				Move to stain room	10	1.5	
24	●					Stain boards	—	1440	
25				●		Wait for stain to dry	—	20	
26		●				Bring to International Designs	—	20160	
27				●		Wait for boards to be screen printed	—	20	
28		●				Pick up boards at International Designs	—	2	
29			●			Inspection	—	.3	
30		●				Move to laminating room	15	.5	
31	●					Clean boards	—	60	
32	●					Laminate boards	—	4320	
33				●		Wait for lamination to dry	—	1	
34		●				Move to drill press	30	.5	
35	●					Redrill	—	.3	
36		●				Move to assembly	15	2	
37	●					Assemble clock mechanism on clock	—	2	
38			●			Inspection	—	2	
39		●				Move to storage	30	.5	
40					●	Storage	—	—	
41									

(due to layover time from the screen printing process) was finalized and the facility layout set up for the production run. The production run was a batch run of thirty clocks. Quality assurance involved checking the material separation processes; including layout, cutting, routing, finish sanding, screen printing, clock mechanism hole and face placement, and final assembly.

Figure 5



Upon completion of the assembly and inspection processes the clocks were distributed to the customers placing orders.

Closing the Loop – Findings and Conclusions

Upon completion of the pilot course several areas for improvement were identified. An analysis of these revealed the following:

- The established timeline was difficult to meet,
- A more detailed motion and time study to balance the flow of the assembly line is needed,
- A more dust-free environment was required to reduce finishing imperfections,
- Jigs and fixtures used in the manufacturing stages were required to reduce inconsistencies in machining processes, and
- A more realistic schedule was required for the production and assembly processes.

Reflection on these findings led to the following conclusions about improvement for the next iteration of the class. These topics should be reviewed more thoroughly to impress their importance on the success of the project. Strategies for improvement should include the following:

- Monitor the timeline on a weekly basis,
- Conduct more than one motion and time study of the assembly line and do additional studies on each of the processes,

- More closely control the finishing process through the use of tack cloths to remove dust specks and dust covers to keep dust from contaminating the finish,
- Initiate the jig and fixture analysis earlier in the design process, and
- Complete a test run of the production and assembly schedule prior to the final production run.

Summary

A senior capstones course can be one of the ways that disciplines can provide evidence to accreditation bodies about what students know and are able to do as a result of instruction received during their years at academic institutions. Program goals which are reinforced by course embedded themes that flow out of the program's mission statement, the use of portfolios, and internship opportunities all ensure that students graduate with the requisite knowledge and skills needed for the workplace. The results of the pilot project conducted in the Technology department appear to suggest that courses taught in the technology department are accomplishing what the faculty intended them to do—achieve the desired program outcome goals/objectives.

The pilot projected conducted by the technology department was successful largely because of several factors which included the manner in which the faculty designed the project, provided timely assistance to students—faculty experts to provide input at crucial phases of the project—and also the outcome of students' efforts—the ability of the student team to produce a viable commercial product. Clockworks realized a 100% return on investment. In addition, the team learned some valuable lessons relating to the overall management of a project—something that might have been difficulty to accomplish if the approach was purely theoretical. The findings from this study revealed areas for improvement such as: meeting established timelines, conducting more detailed motion and time studies for improving line balancing, creating a more dust-free finishing environment, improving jigs and fixtures, and developing more realistic production and assembly processes schedules. In addition, the faculty would develop a more extensive assessment tool – rubric providing students with information about how they can meet or exceed requirements for each of the three evaluation categories. These findings will be evaluated by the faculty and would provide the necessary feedback that may be needed to enhance or improve the overall effectiveness of capstone course.

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C. RAY DIEZ, DIT—Assistant Professor and Chair, Department of Technology, University of North Dakota. Responsible for teaching production processes, product research and development, industrial safety, design/drafting and coordinating the capstone course. Dr. Diez also coordinates the Occupational Safety and Environmental Health baccalaureate program and is Director of department graduate programs.

DAVID N. YEARWOOD, PhD—Associate Professor in the department of Teaching and Learning (T&L), University of North Dakota (UND). Teaches in the T&L Doctorate program with a research specialty focusing on instructional technology and distance education. Previously responsible for coordinating and teaching electronics and computer hardware in the Industrial Technology department at UND

LUKE H. HUANG, PhD—Assistant Professor of Technology at the University of North Dakota. Luke teaches manufacturing automation, cost estimating, manufacturing strategies, facilities design, and materials science courses. Dr. Huang advises several graduate students and conducts research on automating processes using remote sensing and fuzzy logic.