AC 2008-1845: TO BUILD A BETTER BOTTLE OPENER: INTERWEAVING A PROJECT THROUGH THE ENGINEERING TECHNOLOGY CURRICULUM

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To Build a Better Bottle Opener: Interweaving a project through the Engineering Technology Curriculum

Abstract

Many Engineering Technology Programs today are focused on advancing students' skills in communications, teamwork and analytical reasoning along with cross-disciplinary knowledge in order to meet the demands of our global economy. This paper explores how a project interwoven through the Engineering Technology curriculum can instill these skills in the students while enhancing the learning outcomes of the courses. The objective of the project is to incorporate a problem into the classroom that reflects similar complexities to that of real-world problems.

By interweaving the project through the Engineering Technology curriculum, it begins to build on the cross-interdisciplinary knowledge and various skill levels of the students. Students are allowed limited opportunities to integrate and apply knowledge from previous courses and often are not allowed such an opportunity until their senior year through a senior project. This interdisciplinary project also allows for the previous course knowledge to be revisited, reinforced and physically applied.

This project is also intended to enhance the students' engagement in the learning process by allowing the freedom to choose different approaches to problem-solving and communicating their reasoning with other peers, which will encourage more confidence in the individual to approach other problems in life with the same enthusiasm.

The project can also successfully satisfy technology students' desire for more hands-on applications in the educational setting. Many programs are limited by their laboratory capacities. A project such as this one can begin to encourage the utilization of cross-disciplinary resources. The assessment of the project will be an integral part to program assessment activities. Future possibilities for additional applications of interwoven projects will also be explored.

Introduction

Traditional engineering technology courses have been presented and function as stand-alone courses which may or may not reference content connections to other courses within the same program. Today's college student needs more than ever a developed capacity to make sense of this flood of information flowing into his or her consciousness every day. That capacity depends fundamentally on how well she or he can see connections and integrate disparate facts, theories, and contexts to make sense of our complex world (Humphreys, 2005)[1]. The Accreditation Board for Engineering and Technology, Inc. stated that "Integration of knowledge and multidisciplinary perspectives are among the top priorities endorsed by the professions as well. In its report Criteria for Accrediting Engineering Programs, the Accreditation Board for Engineering and Technology argues for advancing integrative learning, including the capacity to work in multidisciplinary teams, as a target goal for future engineering professionals"(2000)[2].

By establishing a link between course content we will also be able to enhance the students' engagement in the learning process by focusing on students and faculty actively working together to formulate a resolution, improvement or theory regarding the issue at hand. Learning involves developing "more sophisticated mental representations and problem-solving abilities by using tools, information resources, and input from other individuals (Windschitl, 2002,pg.137). Windschitl also provided insight into the social aspects of learning by stating,"the world is knowable only through the interaction of knower and experienced phenomenon, learning is an act of both individual interpretation and negotiation with other individuals" (2002)[3].

According to the Association of American Colleges and Universities, "integrative thinkers who can see connections in seemingly disparate information and can draw on wide range of knowledge to make decisions. These thinkers must learn to "adapt the skills learned in one situation to problems encountered in another: in a classroom, the workplace, their communities, or their personal lives"(2002)[4].

Project

One approach to achieving a link between course content would be the weaving of a single project through the engineering technology curriculum. The project can assist with the concepts mentioned above as well as enhance the learning outcomes, offer more hands-on applications and allow for the resolution of problems through a team effort.

Such a project was undertaken in the Mechanical Engineering Technology/ Industrial Technology program at Michigan Technological University. The objective of this project was to incorporate a problem into various classrooms that reflects similar complexities to that of real-world problems, focusing on students actively working together to formulate a resolution, improvement or theory based on their previous and current course knowledge. The project selected during the fall 2007 semester was a bottle opener device.

Project Origin

Most engineering projects used in the classroom are not entirely unique and the bottle opener device is no exception, this device is not an idea originated at this institution but it was adopted from searching the web for something totally different and was happened along by chance through a maze of links from one web page to another. The search started from a simple objective to find dimensional specifications for a bottle opener to use for a 3D modeling and CAM exercise in a Computer Aided Manufacturing course.

By chance a document named "Opening Mechanism" authored by Clerc Jean-Philippe(2002) from the University of Florida outlined a project to develop a mechanically powered mechanism to remove a metal cap from a bottle. An example of Jean-Philippe's model appears in Appendix A, Figure 1 for review. The document went on to describe the steps that the project progresses through such as; using Fourbar and Working Model software to evaluate the lengths of links in the mechanism, hand sketches and 2D drawings for more accurate dimensions, a scale model to test the device range of motion, force gage testing to size the motors necessary, and finally 3D models and a working prototype to test the ability to open a bottle cap effectively.

Related Projects

The article from the University of Florida went on to described the work that Clerc Jean-Philippe did on a robot named ABOR, for Autonomous Beer-Opening Robot, the device moves to a bottle, props an opener under the cap and sends it into the air. The machine's last move is to back away from the bottle.

This idea was again used recently by RadioShack for a media event to market the VexLabs - Vex Robotics parts were used to build the original robot. The robot challenge given was: "design a robot which can grab a beverage off a table, open it, and pour it into a glass." The original concept for the BottleBot, Built by John V-Neun and Chris Carnevale at Innovation First, Inc., was a robot which would pick up a can of soda, puncture the side of the can, then funnel the soda into a waiting glass. This was deemed "not cool enough" and the designers' final concept would grab a long-neck bottle, pop the top off with an opener, then pour over the top into a glass. A picture of the improved BottleBot can be referenced in Appendix A Figure 2. Videos of the robot can also be seen on YouTube.com and Geekologie.com along with an equally impressive Lego bottle opener.

Project Background

The concept for this project took a very different angle than these previous very ambitious examples. Rather than using this idea as a senior design capstone project, the intent was to introduce the project into the undergraduate freshman level courses and incorporate it all the way through the senior level courses. The project would bring students' various levels of knowledge together in solving problems related to the bottle opener as well as enhancing and clarifying course topics.

The first step in using this project was to create a 3D solid model of something close to what was used in the project found online. From the basic design concepts derived from the original "Opening Mechanism" document 3D models in Unigraphics NX 3.0 were constructed by scaling dimensions from the document and using a standard bottle as the scale conversion factor (reference Appendix A, Figure 3). The models were than assembled using mating conditions, so that part modifications could be made without losing necessary positioning of the parts relative to each other. Then, the assembly was analyzed using motion software in NX3 to view the range of motion in the linkage joints relative to the bottle top. The device linkages functioned mechanically in the 3D virtual world as the paper had described. The original design had minor alterations to substitute a 12 volt motor with a different mounting configuration for the two small AC motors.

Project Model

Before integrating the project into the courses as a learning activity it was necessary to build a working prototype of the mechanism. From Unigraphics, 2D detail drawings, which would be used for production, were produced of each component and the completed assembly. Utilizing the expertise of the Training Specialist/Master Machinist and the machine shop facility a complete automatic bottle opening device was constructed, see Appendix A, Figure 4. Minor modifications to the original drawings were made for the adaptation of the motor and electronics, but the size and location of the links remained fixed.

Project Utilization

The goal of interweaving the project into the Mechanical Engineering Technology and Industrial Technology curriculum is to allow students at various skill levels to collaborate on the challenges that come with designing, manufacturing and improving a device to meet specific requirements. Table 1 provides a summary of courses that are impacted to date using this integrative bottle opener project.

Table 1 Courses impacted by project in 2007/2008

Course Number and Title	Course Description	Impact on Program and Students
TE 1010 Technology Computer Applications	*An introduction to parametric modeling and will act as a foundation for additional studies in solid modeling*	*Foundation to parametric modeling. Skill set to be used in following courses.*
MET 2400 Practical Application in Parametric Modeling	*Expand student knowledge of computer modeling techniques, and introduce advanced assemblies and GD&T concepts. Investigate advanced concepts available to the designer.*	*Intermediate course critical to all program concentrations. Provides student with skill set not previously integrated into program*
MET4460 Product Design and Development	*A treatment of design and development issues such as design for manufacturing, prototyping, industrial design, and customer needs. Presents integrated methodologies that examine marketing, manufacturing, and cross-functional teams. Includes concurrent engineering and projects utilizing CAD systems.*	*This course is designed to precursor to the capstone experience utilizing the tools mastered during the students course work. Students organize a team, and meet with an advisor to review the preliminary design concepts, embodiment, and proposed detail documentation of design solution for their senior project.*
MET4580 Facilities Planning, Layout and Process Flow	*This course works through the basics of site selection, plant layout, disaster control, energy conservation, & pollution abatement.*	*Course added to round out requirements for new Industrial Technology Degree*
MET 4660 Applied Finite Element Analysis	*Comprehensive use of both computer derived solutions and experimental validation of analytical and finite element solutions using methods such as strain gages, photo-elasticity and brittle coatings.*	*Course added and required for concentration in Computer-Aided Engineering*

During the 2007-08 fall semester students were introduced to the project in the courses: Technology Computer Applications; Facilities Planning, Layout and Process Flow; and Product Design and Development; and in the spring semester: Practical Application in Parametric Modeling; Applied Finite Element Analysis; and another section of Product Design and Development.

In the Technology Computer Applications class the project is used as the main theme throughout. The students learn basic parametric modeling, assemblies, drafting, motion analysis, CAM and FEA using UG NX3 by constructing the models, creating an assembly, drafting and performing some basic CAM and CAE analysis within the first six weeks.

The remainder of the semester involves teams of students working to develop a critical improvement that needs to be made to the opener. Students learn to utilize the various Microsoft office tools such as Visio, Project, PowerPoint, Word, and Excel to enhance their team objectives and develop their final presentation. The students have the actual working mechanism to observe, test, touch and feel. Each group also continues to strengthen their recently learned Unigraphics skills to design a drawing of their improved mechanism. Some of these new designs are shown in Appendix B.

The Facilities Planning, Layout and Process Flow course used the project in an exercise to create routing operation sheets for each of the separate components, and analyze an existing equipment layout in a facility using string diagrams, and multi column process charts, and from-to diagrams to determine process flow efficiency (reference Appendix C). Finally, they utilize this information to design a more efficient layout of equipment in a facility to manufacture the bottle opener device components. The students in this course are able to have tangible parts that can be evaluated for determining manufacturing procedures with the assistance of the machine shop Training Specialist to describe the machining steps necessary to produce the parts.

In the Product Design and Development course students are introduced to the project as a learning activity to brainstorm ideas for DFM and DFA improvements to the existing design. The bottle opener device was intentionally designed with features that could be improved upon with some application of DFX theory taught in this course. Also, a quality technique taught in this class is the use of Failure Modes and Effects Analysis for manufacturing and for designs (FMEA), where the students create a FMEA chart for design and manufacture of the bottle opener(reference Appendix D). The students can observe and rate the chance for common errors in design or manufacture of the device such as a pinch point during operation of the bottle opener or interference between linkage components.

The Parametric Modeling and Finite Element Analysis courses are advanced classes using the UG NX3 software where the project is used as a practical example of applying the software techniques and textbook theory. The Parametric modeling class is an extension of the Technology Computer Applications class where students will apply advanced modeling in addition to applying geometric dimensioning and tolerances to models. The bottle opener device is used as a practical example for determining the proper fits between mating parts and the true positioning of holes for floating fasteners in an assembly. The Finite Element Analysis course uses UG NX3 software to analyze parts of an assembly experiencing forces during operation as well as in static situations. Using the motion software the maximum loads on the joints are recorded and can be used in the finite element analysis to test if the material is capable of withstanding the force. Since students were introduced to the project in earlier courses, they are familiar with the bottle opener motion and operation.

Enhanced Program outcomes

This project has enhanced many aspects of the learning process: the program outcomes, desire for more hands-on applications in the educational setting and better utilization of laboratory capacities and expenses. The greatest result of this project has been that it allowed for interdisciplinary course knowledge to be revisited, reinforced and physically applied by the students throughout their college courses and not just in their senior year.

A few of the program outcomes emphasized in the Mechanical Engineering Technology and Industrial Technology program include communications, teamwork and analytical reasoning. The incorporation of this project has helped to strengthen these critical skills in our students. The project required students to work together in addressing and resolving the issues set forth by the project. It therefore initiated students to communicate with each other versus mostly with their instructor. This has helped to improve the face-to-face communication skills of the students. In this fashion of communicating with their peers, students can build confidence in communicating their ideas, thoughts and viewpoints as well as gain a sense of ownership in the learning process.

In most instances where team projects are assigned, the students often complain that the workload does not end being equally distributed. This project can begin to create a new (changed) image of teamwork for the students. Since the project links courses together, students are encouraged to provide knowledge from other courses in order to assist with the problem at hand. All students' various areas of knowledge are necessary to complete the project.

Most engineering technology students are interested in opportunities to have hands-on applications in the education setting. This project has responded to students request by providing them with a physical object that can be studied, taken apart, changed and reconstructed. This follows with the model of experiential learning. The focus is more on the active process that the learner goes through to achieve the knowledge. This style of learning places less focus on the instructor conveying the problem and resolutions instead the instructor's role becomes more of a facilitator learning activities.

Evaluation of the project

It was stated at the beginning of this paper that one of the benefits of this project was that it could enhance the program outcomes and course objectives. One example of this can be seen in the data from the student evaluations for the MET 4580 Facilities Planning and Design course and MET 4460 Product Design and Development courses, the students gave an overall rating of 3.47 (on a scale of 1-5) to question 13 which reads Instructional resources (textbooks, handouts,etc.) furthered my learning.

Future Possibilities

This project has only touched on a very small segment of the integrative learning possibilities that can be undertaken and the benefits that can be achieved. A project such as this one can be expanded to include other programs within the school. The future possibilities of this project would be most successful in its ability to link various disciplines to one project while also establishing a connection outside of the academic walls.

Bibliography

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(2) Accreditation Board for Engineering and Technology, Inc. 2000. *Criteria for accrediting engineering programs.* Baltimore: Accreditation Board for Engineering and Technology, Inc.

(3) Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research,* 72(2), 131-175.

(4) Association of American Colleges and Universities. 2002. *Greater expectations: A new vision for learning as a nation goes to college.* Washington, DC: Association of American Colleges and Universities.

(5) Jean-Philippe,C., Qaiyumi,A.(2002). Autonomous Bottle Opener Robot. Unpublished manuscript, University of Florida. Retrieved December 14, 2007 from http://www.mil.ufl.edu/imdl/papers/IMDL_report_spring_02/Jean-Philippe Clerc/Arsor.

Appendix A

Figure 1.
Clerc Jean-Philippe model

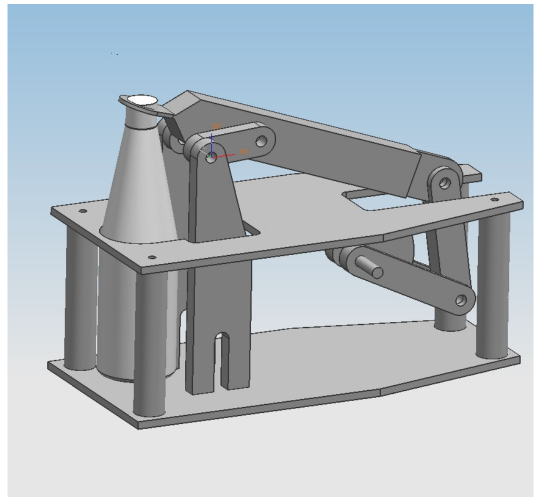


Figure 3
Opening Mechanism

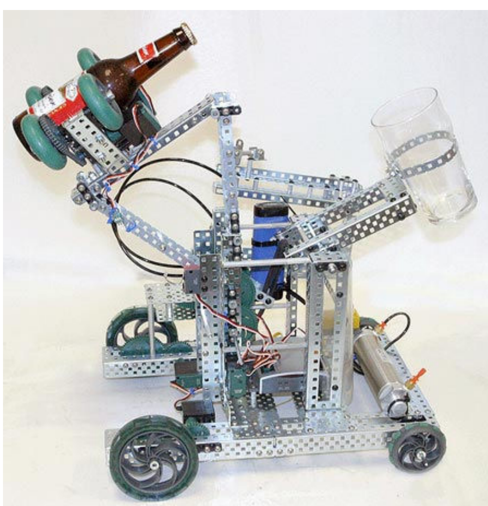


Figure 2
Bottlebot

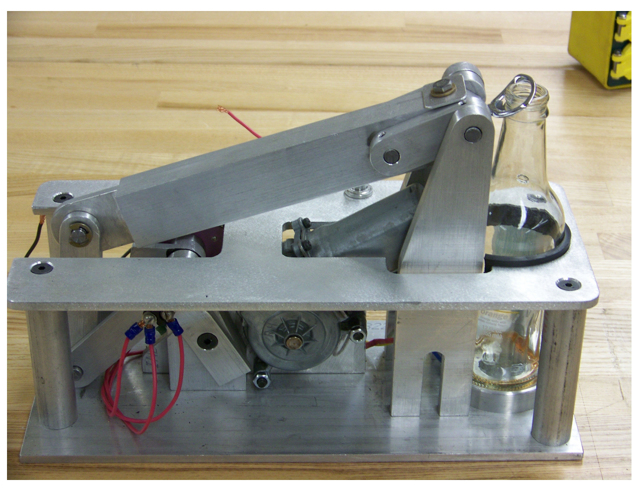


Figure 4
Completed automatic bottle opening device

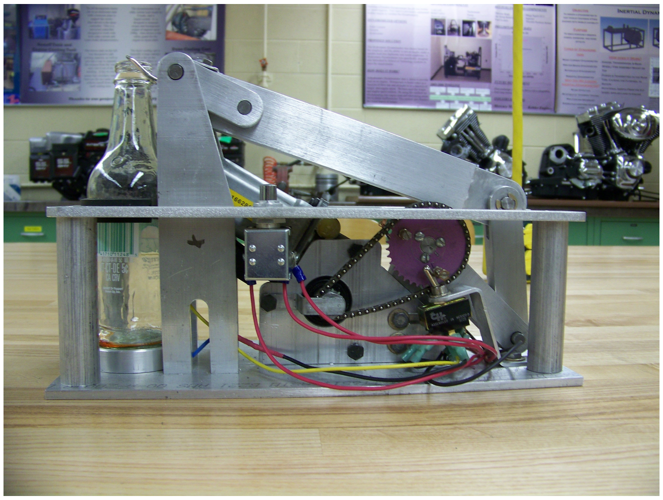
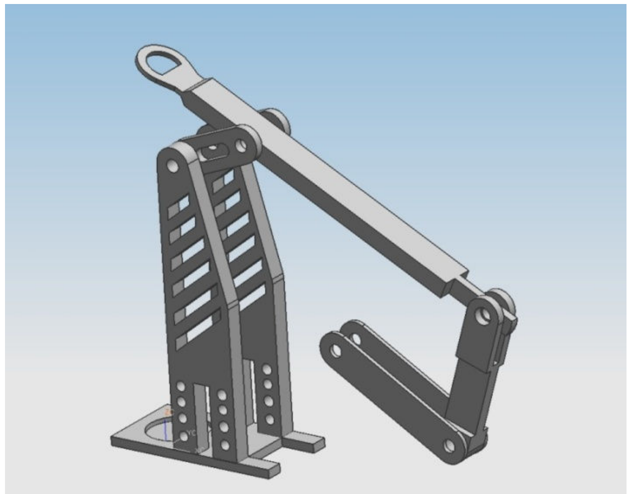
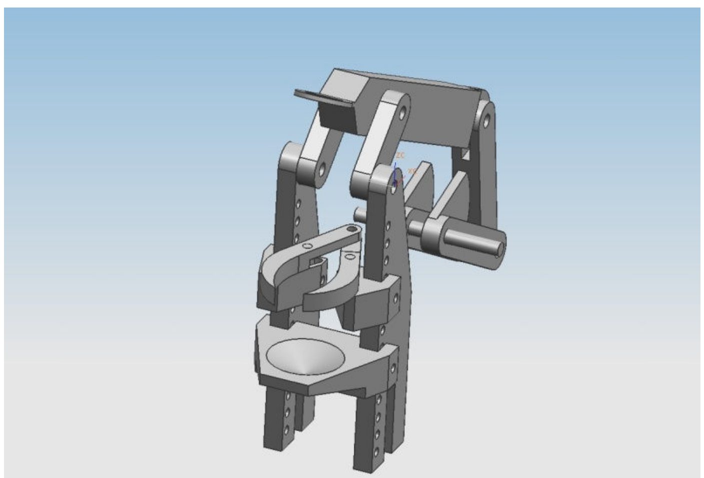


Figure 5
Side view of bottle opener

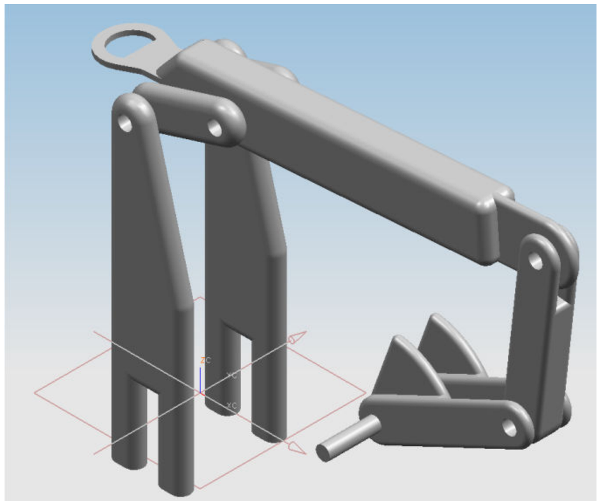
Appendix B
Possible enhancements



New design-weight reduction



New design of holder

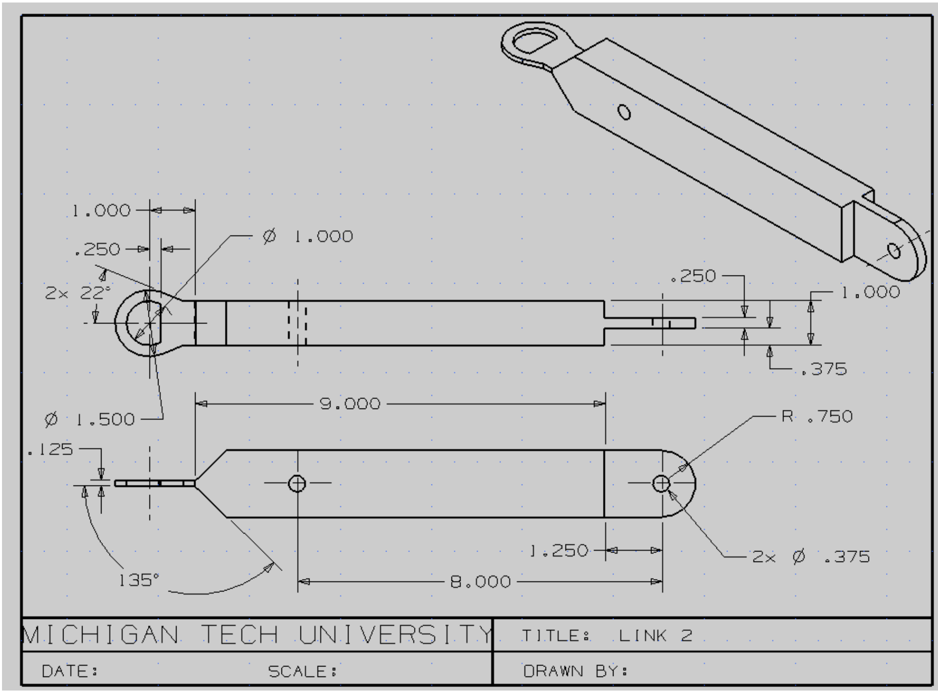


New Design-smooth edges

Appendix C
Example of Course utilization

Part Operation Sequencing – MET 4580 Facilities Planning, Layout and Process Routing sheet

Part Name: Link 2 Material :			**Drawing Number: 1010 - 002**
No.	**Operation Description**	**Machine**	**Comments/Special Tooling/gages**
005	Pull material from storage	Material Crib	
010	Cut to length	Cut-off Band Saw	
015	Drill 2 x .375 Ø holes	Drill Press	Drill Jig TL-DJ-004
020	Mill Both Sides to shape .250 web	Vertical Mill	Milling Fixture TL-MF-006
025	Cut .750 Radius	Vertical Mill	Milling Fixture TL-MF-007
030	Cut 135° Angle	Band saw	
035	Drill for opener	Drill Press	Drill Jig TL-DJ-005
040	Break all sharp edges	Belt Sander	
045	Deliver to Assembly	Assembly Bench	Manual Inspection Gages
050			

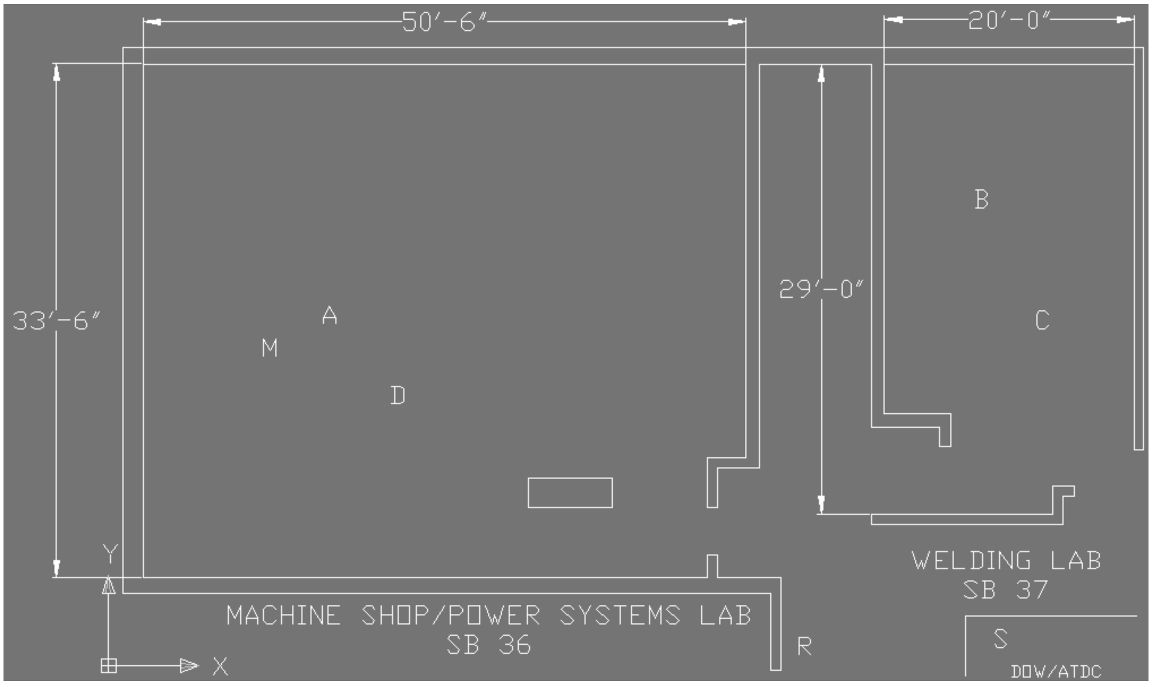


Flow Analysis & Activity Relationships – MET4580 Facilities Planning, Layout & Process

- ## Data Gathering

The lab was to layout the accessories of a bottle open product in EERC SB-36 lab in order to make the fabrication process more efficient.

General Arrangement in EERC SB-36:



Existing Equipments Arrangement

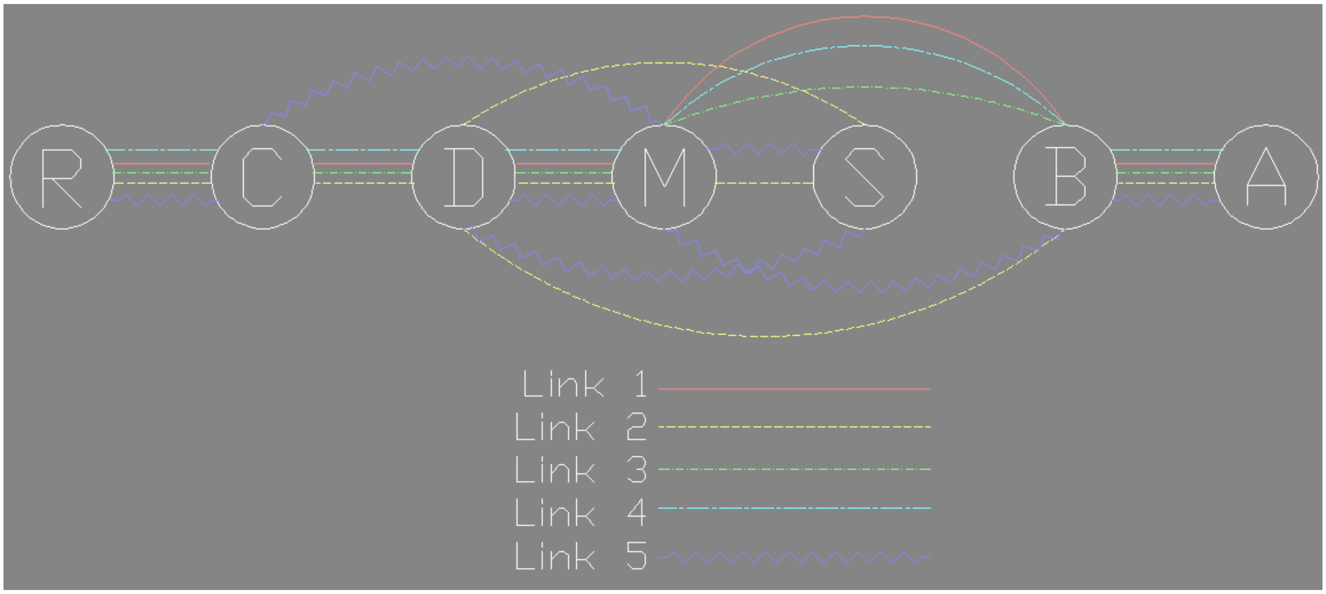
R	Material Crib	Hallway
C	Cut-off Saw	SB-37
B	Belt Sander	SB-37
S	Band Saw	Dow/ATDC
D	Drill Press	SB-36
M	Vertical Mill	SB-36
A	Assembly Bench	SB-36

- ## ANALYSIS AND RESULTS

Link No.	Routing(Operation Sequence)
1	R C D M B A
2	R C D M M S D B A
3	R C D M M B A
4	R C D M M B A
5	R C M D S M B A

Im
pro
ved
Lay

out – R C D M S B A



Multi-Column Process Chat						
Part Numbers						
	1	2	3	4	5	
R	O	O	O	O	O	
C	O	O	O	O	O	
D	O	O O	O	O	O	
M	O	O	O	O	O O	
S		O			O	
B	O	O	O	O	O	
A	O	O	O	O	O	TOTAL
# STEPS	6	10	6	6	11	39
LEAST STEPS	6	6	6	6	6	30

Efficiency = 76.92

From-To Chart

	R	C	D	M	S	B	A	PP	T
R		5(5)						5	5
C			4(4)	2(4)				8	6
D				4(4)	2(4)	3(6)		14	9
M					1(1)	8(16)		17	9
S			2(4)	1(2)				6	3
B							5(5)	5	5
A								0	0
PP	0	5	6	7	3	11	5	55	37
									37/55
									67.3% eff

Appendix D
Example of Course utilization

FMEA Example from MET 4460 Product Design & Development

System	Bottle Opener	FMEA Number	
Subsystem		Prepared By	
Component		FMEA Date	
Design Lead		Revision Date	
Core Team		Page	of

Potential
Failure Mode and Effects Analysis
(Design FMEA)

Key Date

Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Prob	Current Design Controls	Det	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	New Sev	New Occ	New Det	New RPN
Joints - They are used to connect different links in the mechanism	Joints can loosen and cause the mechanism to droop	Sufficient strength is not delivered at link 2 to remove the cap	5	Prolonged use, i.e. ageing leads to this	7	Joints made with nuts and bolts so that tightening is possible whenever required	3	**105**	Tighten the joints after every 100 uses.						
Wires - They are used to transfer electric current from motor to the mechanism	Wires may break if they come in the way of the moving links	The system will stop functioning as power is not supplied to the links	8	Wires may come between moving links and other components and break.	5	Wires are shoved under the top horizontal plate	2	**80**	Use adhesives to stick wires under the horizontal plate so that they do not dangle and get caught in the moving links						
Motor - It drives the mechanism	Motor can burn out	The system is rendered useless	7	Motor can overload due to prolonged use	5	None	4	**140**	Install a mechanism to disconnect the motor when it reaches certain temperature.						
Link 2 - It opens the bottle cap	Shape deformation	Performance is degraded. Bottle positioning and/or orientation has to be changed	4	Poor selection of material. Improper positioning of the bottle	6	Top horizontal plate to secure bottle in position	3	**72**	Perform FEA on the link for stress analysis on the link before installing.						
Link 2 - It opens the bottle cap	The link might not reach the bottle cap to remove it	The system is no good as it does not serve the purpose	7	The height that the link can reach is limited	7	None	2	**98**	Incorporate a mechanism to raise or lower the bottle so that the link can reach the cap						