120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013
Paper ID #7293

Teaching Manufacturing With Group Cell Practices

Dr. Wayne P Hung, Texas A&M University

Dr. Wayne Hung graduated from the University of Michigan at Ann Arbor and University of California at Berkeley. Dr. Hung is currently an Associate Professor at Texas A&M University. Dr. Hung's research interests include novel materials and micromanufacturing.

Mr. Wm Adam Farmer, Texas A&M University

TEACHING MANUFACTURING WITH GROUP CELL PRACTICES

Abstract

In traditional manufacturing lab exercises, students lean to operate one type of machine tool at a time. After learning each machine type, they then move to another type and learn all operations on new machine tool. There is little connection and interaction among students since each person will produce his/her own individual part. At the end of training lessons, some instructors may verbally describe the link of different processes and how a product would flow among those processes. A manufacturing department typically has to purchase many identical machine tools and different tooling sets for variety of possible operations on each machine type. The operating cost of such manufacturing laboratory is high and some students might not comprehend the link among different processes. This model is popular among community colleges or vocational schools, but may not be best for engineering students since the latter only need to understand the manufacturing processes rather than acquiring hands-on manufacturing skills.

We propose a new manufacturing teaching practice at our university by introducing group cells and simulated production lines. A group of students is responsible to produce products for the whole group. After learning and practicing basic machine tool operations in a cell (lathe, mill, sawing machine, and specific manual operations), each subgroup of two students operate a machine tool and produce identical components for the whole group. Students will have option to rotate to other machines or stay with a specific machine to gain more experience. A student keeps time record of selected operation for time study. When all components are produced to drawing dimensions and tolerances, students then assemble components to form the final products that are carefully designed for process integration while having meaningful value and ecstatic appearance for students to keep. In the concluding session, a teaching assistant leads the discussion and highlight the capabilities of each machine, flow of parts from one machine to the next, identify the bottle neck station and let students suggest corrective actions at the conclusion of the lab exercise. Component dimensions and part shape are modified for different groups to illustrate how a family of parts is produced in group cells and the advantages of flexible manufacturing concept.

The implementation of Group Cell practice will start in the Fall semester of 2013. Data from student feedback and quiz grade distribution will be collected to gage the impact of Group Cell on student subject comprehension.

Introduction

Group cell technology is popular in industry. This technology utilizes group of specific machines to fabricate family of parts that have common features. Manufacturing using group cells, or cellular manufacturing, cuts down setup time, engineering cost, inventory, product development time, and purchasing time while simplifying process planning and procurement [1,2].

A typical manufacturing laboratory is equipped with rows of identical machines, where students learn in sequence from one type of machine to another. Although students would repeat a demonstration and interact with their instructor, they rarely interact among themselves and often miss the link among different processes. The concept of group cell and all of its advantages can be applied in academics since students normally practice to fabricate similar components in different semesters. This new approach is proposed to replace the traditional manufacturing laboratory practice. Group cells with different machines are utilized rather than having duplicated of same machines. The objectives of this paper are to:

a) Compare the Traditional and Group Cell approaches for university students
b) Presents an example of machining laboratory exercise.

Literature Review

In education, hands-on laboratory practice is the key to effective learning. "I hear and I forget. I see and I remember. I do and I understand" was preached by the famous teacher and philosopher Confucius (551–479 BCE) during Spring-Autumn period of Chinese history. Leighbody and Kidd also concluded "learning requires active experiences" in their survey[3].

Nowak[4] ranked teaching strategies and learning activities within technology education. The highest ranked strategy was the one with product-oriented and laboratory-based content. The second highest rank was for strategy using technology focus, and the lowest was for strategy that relied heavily on classroom orientation.

Having hands-on laboratory is one condition, but the laboratory practices should be relevant to prepare graduates for their manufacturing career. Miller[5] surveyed 25 department heads of US manufacturing programs and concluded that an exemplary manufacturing program should:

a) Require more technical coursework
b) Require or strongly encourage cooperation with industry
c) Maintain closer relationships with industry
d) Has more manufacturing faculty and students
e) Place a greater emphasis on teaching
f) Provide numerous, well-equipped facilities
g) Produce graduates more knowledgeable of materials and processes.

Nelson[6] analyzed inputs from directors of ABET accredited programs to identify key technical competencies for manufacturing graduates. Among 264 competencies, the highest ranked competencies related to quality, communication, and personal ethics. Baird[7] proposed a laboratory exercise to simulate mass production environment. Although is more difficult to develop this type of exercise compared to the traditional teaching practice, the benefit of the latter approach is numerous since:

a) It simulates industry practice,
b) It develops specific hard-skill and soft-skill of students,
c) It provides opportunity for lab instructor to be creative and organized, and
d) It significantly enhances team communication and cooperation among team members

Approach

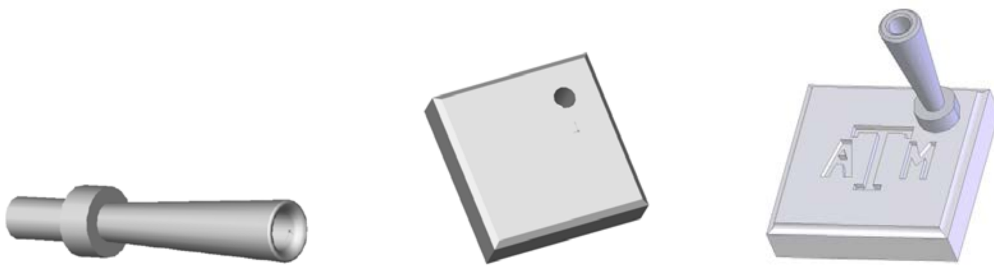
Most manufacturing practices focus on developing hard skills for students and miss the soft-skill component. A typical laboratory exercise would identify the purpose, list required equipment and materials, and provide detailed step-by-step procedure. A laboratory instructor would demonstrate the steps and let students to repeat using identical machines. The next laboratory exercise would repeat for different type of machines. This traditional approach employs laboratory instructors with specific expertise to manage each type of machines, requires a large floor space for multiple machines, and is lack of interaction among students.

The traditional laboratory approach provides hard-skills to students, while group-cell laboratory approach provides both hard-skills and soft-skills to graduates. Group cell requires unique machines to fabricate similar products. Although it is more cost effective, group cell approach requires lots of preparation and effective communication. The following table compares the two approaches.

Table 1: Comparing laboratory approaches

Criteria	Traditional Laboratory	Group-Cell Laboratory
Equipment	Multiple numbers of identical machines.	Duplicate cells, each with unique machines.
Tooling	More (due to number of machines)	Less
Lab floor space	More	Less
Maintenance and operating cost	More	Less
Instructor	Central expertise. Each instructor is an expert of one machine type.	Broad expertise. Each instructor must know all machines in a cell.
Teamwork	Limited. Each student repeats what the instructor did.	Significant. Students manage the flow of material from one machine to the next.
Material flow and parts	Single part. Does not see part variation.	Group of parts. Measure dimensional variation.
Preparation	Less. Instructor demonstrates process on one machine at a time.	More. Instructor demonstrates process for each machine, and suggests flow among different machines.
Industry relevant	Less	More
Overall cost	More	Less

Example of Group-Cell Exercise



(a) (b) (c)

Fig. 1: Parts for machining exercise (a) pen-holder, (b) pen-base, and (c) complete assembly.

Figure 1 show the pen-holder assembly that we used in the past for Traditional approach and will use again in Group-Cell for comparison in coming semesters. There are 14 groups with 16 students in a group, and it takes five 2-hour sessions to complete this introductory machining exercise in freshman level course. Time study is done during a separate study in the Traditional approach, while it is embedded in the Group-Cell approach. At the end, each student will have his/her own set for CNC engraving in the next exercise. Tables 2 and 3 compare the setup and scheduled activities in each case.

Table 2: Laboratory setup

Criteria	Traditional Laboratory	Group-Cell Laboratory
Equipment	- 5 lathes - 5 vertical mills - 2 drills - 2 vertical saw - 1 horizontal saw	2 cells, each with: - 1 lathe - 1 mill (horizontal or vertical) - 1 drill - 1 saw (horizontal or vertical)
Lab floor space	1420 ft^2	600 ft^2
Instructor	2 per session	2 per session

Table 3: Schedule breakdown

Session	Traditional Activity	Group-Cell Activity
1st	Lathe	Introduction
2nd	Lathe	Saw, drill, mill, lathe, time study
3rd	Saw, mill	Saw, drill, mill, lathe, time study
4th	Drill, mill	Mill, lathe
5th	Time study	Mill, lathe

In the first session of Group-Cell practice, an instructor for each cell will cover the basic operation for each machine in the cell. Eight students per cell will learn how to set up tooling for each machine, and practice basic machining. In the following sessions, it is flexible for students to choose their roles while working together in a cell.

- The group will produce parts for everyone to simulate production mode
- Time study will be imbedded in selected operations

- Students work in subgroup of 2. They can choose to stay with one machine (expert) or rotate to learn other processes
- Students are responsible for checking dimensions of their parts
- Label parts number 1-16
- Students to select group representative and choose their roles

Table 4: Student role in a Group-Cell (enter names in available blocks)

#	Duty	Description	1st session	2nd session	3rd session	4th session
1	*Group Representative.	– Keep overall record – Report issues				
	Group Assistant	Assisting Group Representative				
	Metrology	*Master				
2	Metrology	Assistant				
3	Saw	*Master				
4	Saw	Assistant				
5	Drill	*Master				
6	Drill	Assistant				
7	Mill	*Master				
8	Mill	Assistant				
9	Lathe	*Master				
10	Lathe	Assistant				

* Student who stays and gains more experience on a specific role/machine/equipment

The following tables are provided to guide students in each operation. There are four main activities: sawing, drilling, lathe turning, and milling. Time study is included in some activities.

<u>Sawing operation:</u> Student will saw the round rod or rectangular bars at different combinations to study the effect of setup.

- Saw rods and bars to required lengths
- Use different sawing setup for time study
- Record sawing time for block sawing

Table 6.1: Activity for sawing operation for each cell. Note the bar orientation and number of bar for each cut.

	Sawing operation		
	Blue horizontal saw → ϕ0.75x4" rod	Horizontal saw → 3x3x0.75" block	Vertical saw → 3x3x0.75" block
1st session	8* 	2*  + 4* 	2* 
2nd session	8* 	2*  + 4* 	2* 

*This indicates numbers of parts after cutting.

Record the observe time (setup time + machining time) to produce a single part.

Table 6.2: Time study in sawing for each cell. Note the bar orientation and number of bar for each cut.

Sawing setup	Horizontal saw		Vertical saw	
	Start/End time	Time for 1 part	Start/End time	Time for 1 part
				
				
				
				

Conclusion: The best setup is ___________

Drill, mill, and lathe operations: Parallel activities are expected at these stations. Time study is included for milling only.

- Mill the blocks using either horizontal or vertical machine
- Use different milling setup for time study
- Record milling time

Table 6.3. Activities for drill, mill, and lathe. Note the block orientation and number of blocks in milling operation.

	Drill/Grind	Mill (choose one) __horizontal __vertical	Lathe
1st session	• Center drill • Drill →4 blocks	• 2 (single side) • 1 (double sides) →4 blocks (2.9x2.9x0.75")	• Face, center drill, drill →8 rods
2nd session	Repeat 1st session	Repeat 1st session	• Machine 5° taper →8 rods
3rd session	Grind	• Mill to thickness →8 blocks (2.9x2.9x0.70")	• Turn ϕ0.6" and ϕ0.5" • Groove square shoulder →8 rods
4th session	Grind	• Groove edges →8 pen-bases	• Knurl ϕ0.6" surface • Part off →8 pen-holders

Record the observe time (setup time + machining time) to produce a single part.
Table 6.4. Time study for milling. Note the block orientation and number of blocks in milling operation.

Milling setup	Horizontal mill		Vertical mill	
	Start/End time	Time for 1 part	Start/End time	Time for 1 part
Single				
Tandem				

Conclusion: The best setup is ____________

Table 6.5. Quality assurance using Go/No-go gages.
Pen-bases. Check (√) if within tolerance.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Thickness 0.7±0.01"																
Hole size ϕ0.500-0.510"																

Pen-holders. Check (√) if within tolerance.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
End cylinder ϕ0.487-0.497"																

At the end of the exercise, a Teaching Assistant will lead the group discussion and highlight:

- Critical dimensions of the parts and how to control them.
- Capability of each machine.
- Contrast of different machine type (e.g., horizontal versus vertical mill).
- Flow of material.
- Possible shape change of the product giving the same machines in a cell.

A follow up clicker quiz will be implemented to gage the student comprehension of the group cell and basic processes, and to study the impact of Group-Cell practice.

Discussion

Floor space saving, lower setup and operating cost, teamwork enhancement, and industrial relevancy are some benefits of the Group-Cell approach. The rigid Traditional approach has been applied in the past decades to provide uniform training to all students at high schools, community colleges, vocational schools, and universities. However, manufacturing engineering or technology students at university level, who might not require the same training as technicians, should have options in a more flexible system. The proposed Group-Cell approach at our university is cost effective, flexible, and team-oriented since it allows students to choose their roles while learning the basic hard-skills.

We have transformed our current machining laboratory into two group cells in a smaller area, and allocated the saved floor space to other activities. The brand new machines at two group cells, although can have similar functions and capabilities, are different so students can experience and compare. One cell has a horizontal mill and horizontal saw while the other is equipped with a vertical mill and vertical band saw. The two lathes and two drills also come with different accessories and options. All students will have a chance to practice basic machining operations and rotate to other machines during the first session and then select their roles for the remaining sessions. Therefore, some students can choose to work on specific tasks to gain deeper knowledge, e.g. metrology or lathe machining, while others can opt to rotate and work on different tasks to gain a broader perspective.

The new Group-Cell approach for machining exercise will be implemented in the Fall semester of 2013 before duplicated models are implemented to other laboratory exercises. The same parts, inherited from previous Traditional machining exercise, are used in the Group-Cell exercise. This way we can (i) minimize training effort to our current Teaching Assistants, and (ii) have the same base to gage the student subject comprehension. Data from student feedback, comment from industrial advisory committee, and laboratory quizzes will be used to gage the success of this Group-Cell approach.

Summary

We propose and implement Group-Cell laboratory practices to replace the Traditional laboratory exercises. Teaching manufacturing through simulated production line in a group cell would provide both hard-skills and soft-skills to students since this approach:

a) Simulates industrial practice,
b) Provides opportunity for students to interact and be responsible, and
c) Reduces floor space and expenses when having less number of identical machines and tooling.

Although very promising, the impact of this new approach is yet to be verified with feedback data and assessment of student comprehension.

References

1. Askin, R.G. and Standridge, C.R., *Modeling & Analysis of Manufacturing Systems*, John Wiley & Sons publisher, 1993.
2. Strategos, http://www.strategosinc.com/group_technology.htm, access date 5 January 2013.
3. Leighbody G.B. and Kidd D.M., *Methods of Teaching Shop and Technical Subjects*, Delmar publisher, 1966.
4. Nowak, M.L., *Identification of Teaching Strategies and Leaning Activities for Manufacturing Technology Education Programs*, Dissertation, Texas A&M University, 1988.
5. Miller M.R., *Strategies for Developing an Exemplary Program in Manufacturing Engineering Technology*, Dissertation, Texas A&M University, 1993.
6. Nelson M.S., *Technical Competencies for Entry-Level Manufacturing Engineering Technologists for the Year 2000*, Dissertation, Texas A&M University, 1992.
7. Baird R.J., *Contemporary Industrial Teaching*, Goodheart-Willcox publisher, 1972.