AC 2012-5421: ENHANCING STUDENTS LEARNING THROUGH MILL CONCEPT

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Enhancing Students Learning Through Manufacturing Integrated Learning Lab (MILL) Concept

Abstract

Hands-on-experience is one of the key aspects of effective students learning in engineering and technology education. The lack of hands-on experiences in specific engineering processes has been identified as one of the major competency gaps in engineering & technology education. Models such as Learning Factory and Manufacturing Integrated Learning Laboratory (MILL) are designed to improve students' learning through hands-on experiences. The MILL model, developed by the Wayne State University, focuses on integrated learning. The core of the MILL concept is the use of projects spanning multiple courses to help students gain hands-on experiences in design and manufacturing. It involves the coordination of realistic hands-on activities in targeted courses around the unifying theme of designing and fabricating a functional product. These activities are suited for easy implementation in a typical design and manufacturing teaching lab. Even though the MILL model was designed and implemented in manufacturing education but can be used in other engineering and Technology disciplines such as logistics and supply chain.

The MILL concept has been implemented successfully in many manufacturing and design programs but almost none in logistics programs. The MILL model was implemented in logistics curriculum of a US university. This implementation improved the ways of learning for students, focusing on implementing the MILL model in a series of courses that covered five logistics and supply chain courses. Nowadays engineering and technology graduates are performing multi-disciplinary tasks in their work place. Implementing the MILL in a multi-disciplinary area will prepare them to do the challenging job. The implementation of MILL was done in several different courses that were proven effective for students to connect the dots of real life job environment. Assessment results show positive impact on students learning due to MILL implementation.

Student learning techniques

Students learn differently. It is very important to understand how individuals learn and comprehend. Examples of well-known learning models include: The Felder-Silverman Learning Style Model (Table 1), Myers-Briggs Type Indicator, Herrman Brain Dominance Instrument, and Kolb's Learning Style Model. "These various frameworks fall into three general categories that represent schemes to focus on the learner: 1) information processing, which tend to employ various tests to pinpoint differences in cognition and perception; 2) personality patterns, which deals with the effects of environment and socialization, and 3) perceptual modality, which addresses biologically based reactions to the physical environment[1]. The FSLSM model is applicable to the proposal because it highlights the inconsistency in teaching methods to learning methods in a modern learning environment.

Table 1: The Felder-Silverman Learning Style Model[2]

sensing learners (concrete, practical, oriented toward facts and procedures)	vs.	*intuitive learners* (conceptual, innovative, oriented toward theories and meanings);
visual learners (prefer visual representations of presented material--pictures, diagrams, flow charts)	vs.	*verbal learners* (prefer written and spoken explanations);
inductive learners (prefer presentations that proceed from the specific to the general)	vs.	*deductive learners* (prefer presentations that go from the general to the specific);
active learners (learn by trying things out, working with others)	vs.	*reflective learners* (learn by thinking things through, working alone);
global learners (holistic, systems thinkers, learn in large leaps).	vs.	*sequential learners* (linear, orderly, learn in small incremental steps)

Most engineering & technology students are visual, sensing, inductive, and active, and some of the most creative students are global; most engineering education is auditory, abstract (intuitive), deductive, passive, and sequential[2]. This particular study is geared toward engineering students but the implications are clear for any educator. If institutes of higher education mismatch

education style with student learning style it leads to poor student performance, professional frustration, and a loss to society of many potentially excellent engineers/students[2].

Additional research using the VARK determination of learning style at Georgia State University has determined that the majority of students across a wide range of academic majors respond well to two or more styles of learning. The acronym VARK stands for visual (V), aural (A), reading/writing (R) and kinesthetic (K) modalities, respectively. In fact the majority of students in the study responded to three or more styles of learning simultaneously. There is a difference between how male and female students learns. Table 2 shows learning preferences of male and female students.

Table 2: Cross tabulation of learning preferences of male and female students[1]

| | | Learning Preferences of Male and Female Students | | | | | | | |
		V	A	R	K	Bi mode	Tri Mode	MM	Total
Female	% within Gender	1.3%	10.5%	14.5%	11.8%	13.2%	9.2%	39.5%	100.0%
	% of Total	.5%	3.8%	5.3%	4.3%	4.8%	3.4%	14.4%	36.5%
Male	% within Gender	3.0%	9.8%	7.6%	14.4%	22.7%	14.4%	28.0%	100.0%
	% of Total	1.9%	6.2%	4.8%	9.1%	14.4%	9.1%	17.8%	63.5%
Total	% total	2.4%	10.1%	10.1%	13.5%	19.2%	12.5%	32.2%	100.0%

Additional data identified that 60.9% of logistics students prefer a learning style that includes multiple methods of learning stimulus[2]. Today's classroom can be an amalgamation of all types of learning styles. Therefore, it is critical for educators to teach using a variety of styles in or to accommodate a diverse student body.

Learning factory concept

The Learning Factory concept has been developed in response to an identified gap in engineering education that leaves students with theory based knowledge without any practical application experience. Learning Factories have been utilized as a means of maintaining the "appropriate balance between preparing graduates for immediate usefulness in the workplace and providing them with a more fundamental knowledge that would allow them to continue their education and

be more useful in the long run[3]". The driving premise behind Learning Factories is that the traditional method information delivery, i.e. the lecture, is not the most effective way to educate future engineering students. This belief is driven by the belief that traditional "lectures encourage passivity in students, leading them to expect the instructors to provide all the necessary knowledge[4]". The argument is that lecture based learning does not accommodate a variety of learning styles into the curriculum.

In addition to addressing the curriculum needs of engineering students for the 21st century, Learning Factories provide the opportunity for industrial partnerships between participating universities and companies representing the full spectrum of engineering needs, from multinational companies to small family owned businesses. Industrial Partnerships provide a means of academic institutions to work closely with a given industry to determine the skills necessary to modern day engineering practices. "Feedback from industry keeps attention focused on the necessary skills and knowledge base that students require, and how these elements should be integrated into the academic experience[4]".

Learning factory curriculum

The Learning Factory concept consists of a curriculum that "enables students to integrate design and manufacturing issues[4]" into their overall learning experience. "This curriculum makes extensive use of case studies, active learning techniques, and computer technologies in the classroom, and provides previously unavailable opportunities for hands-on engineering experience in the Learning Factory[5]". In this curriculum, Learning Factories are physical facilities located on the campuses on host universities that provide students with the necessary equipment and technology to actively learn and address complex engineering issues. In some cases, students will have access to small scale production lines to further add to the realization experience. "The basic principle of the Learning Factory is integration – integration of design and manufacturing experience into the undergraduate curriculum; integration of equipment and materials into manufacturing systems; and integration of people from several different engineering and business disciplines into effective teams that design and produce products and

processes[5]". Students must opt-in to the Learning Factory curriculum which, for university purposes, is considered a minor or degree option called a Product Realization Minor (PRM).

Students select to participate in PRM beginning in their freshman year studies. The "curriculum consists of a progression of design and manufacturing courses, approximately one per term, allowing students to practice their engineering science fundamentals in the solution of real problems[4]". Each term of study, students who select the PRM options are tasked with projects that allow them to apply concepts learned in the Learning Factory environment that focuses on high volume manufacturing. In addition to facilities and technologies, students will also have access to a staff of students and professors who assist with product realization tasks. Students are assigned one project per semester until their senior year of study. The curriculum is rounded off with a capstone project that encompasses the final year of study. "This capstone course provides students with the opportunity to practice the design of products, processes and enterprise from conceptualization to actualization[5]".

Learning factories issues:

The Learning Factory concept has been a work in progress for the last decade. The Learning Factory concept was revolutionary from its inception. However, after executing the program there have been a number of issues identified with the LF concept. The first issue of significance is that projects are fragmented by year. Students are tasked with one project per term of study, excluding the senior capstone project. While students are assumed to be working in a collaborative supportive environment, there is still a silo effect in learning. Students learn one portion of the engineering process then move onto the next step. There is not continuity to the project process. So, students will spend untold hours working on one project for a learning purposes, then move onto another project the next term. Students are not tasked with full conceptualization to actualization of a project until their senior year. This could facilitate a gap in linking abstract concepts to one another.

Another issue regarding the LF concept is that students must be present on campus to participate in the program. In the current academic environment students are continuing to embrace the

nontraditional route of distance learning for their studies. The LF model hinges on a physical facility for students to pursue their PRM. If the trend for institutes of higher learning is more online based class offerings there is major gap in the LF concept to accommodate distance learning students.

The current LF concept offers students the opportunity to take an abstract idea from conceptualization to actualization for high volume manufacturing purposes. This focus on high volume manufacturing does not necessarily constitute the majority of manufacturing environments. The curriculum could facilitate students choosing the appropriate manufacturing method, such as high-mix low-volume manufacturing methods. This would allow students to customize their learning experience and potentially benefit companies more as they receive students who are highly adaptable and analytical thinkers.

The LF concept is inherently expensive. Institutes of higher learning must commit to providing physical facilities, staff, cutting edge technology, and in some cases full production lines for students pursuing a PRM. The original partners in the LF envisioned a widely applicable model of learning for students pursuing studies in technical fields; however, the initial outlay of capital may prohibit many colleges and universities from considering the concept. Additionally, when production lines are utilized the product of the work intensive process is purely academic. Student take a product through every facet of the production cycle then produce a product that is of little use in the real world. The LF concept could benefit from partnering with industries for the purposes of producing a tangible product that could be implemented into real world operating environments. Industrial partners could use LF as research and development laboratories.

Manufacturing integrated manufacturing laboratory (MILL)

The Manufacturing Integrated Manufacturing Laboratory is a cheap cost alternative of the Learning Factory concept. This effort to further develop the Learning Factory concept results from the aforementioned problems inherent in the design of the model. Researchers have noted that many institutions of higher learning and reluctant to implement the LF model into their

curriculums due to high cost and not accommodating distance learners. The MILL model builds off the progress of the LF model with number of adaptations, to include[6]:

- Students focus more on computer aided design rather than conceptualization or functional analysis. This is appropriate for Engineering Technology programs.

- Activities in all courses will be centered on selected model programs (one per semester). This retains realism while using less expensive yet robust machines.

- Working student population serviced provides inherent collaboration with the industry. This is reflected in student's senior project course. Upgrading laboratories will allow students to undertake more industry-based real life projects.

- No new programs are needed for development because the MILL model will be integrated into existing courses. This allows for increased transferability between programs.

One of the tenets of the MILL model is the "careful coordination of the various hands-on experiences in the targeted courses[6]". The designs used in early courses are to be utilized in subsequent courses as the focus of process planning. The goal is to provide continuity to the learning experience. Students will gain in-depth knowledge of manufacturing processes in a sequential order; while at the same time have access to a variety of learning methods in one course.

Implementation of MILL model in logistics & supply chain curriculum

The MILL model was implemented to include applications in *logistics and Supply Chain Management* program in a US university. This Extending MILL project was implemented in a sequence of five courses. These courses are AEC 132: Drafting; AEC 320: Auto CAD; IET 350: Cost Control; IET 370: Logistics Operations; and IET 400: Senior Capstone Project. The sequence of these courses are designed in way so that students can get a comprehensive hands-on experience on drawing, designing, costing, manufacturing, and distribution of sample product. In this case, the curricular innovations were based on the five courses shown in Table 3 which are currently offered at the particular university.

Table 3: Targeted Logistics Courses and Their Learning Objectives

Course# and Title	Learning Objectives
AEC 132 & 320 Drafting and Auto CAD	• Introduce students to basic engineering drawing, drawing using Auto CAD software. • Develop understanding of critical dimensions of engineering parts, 3D visualization using computer. • Develop critical thinking, assessment, and problem solving skills of students.
IET 370 Logistics & Operations Concepts	• Define technical terms, understand basic concepts, and describe the algorithms for solving linear and integer programming problems. • Identify a number of situations which can be analyzed using linear or integer programming and set up models that correctly represent the significant features of each. Correctly interpret model solutions in terms of the original problem and present them in understandable terms. • Perform necessary conversions and solve models, using graphical methods and hand calculations for small models and computer programs for larger ones. • Use LINDO and LINGO to solve linear and integer programming problems.
IET 350 Industrial Cost Control	• Introduce students to cost estimation, cost improvement, and cost calculations. • Develop understanding of why cost analysis is a key component of industrial engineering. • Develop critical thinking, assessment, and problem solving skills of students. • Develop competency in the techniques applicable in industrial engineering practice or for furthering education.
IET 400 Senior Project	• Develop ability to work on a significant real world engineering problem while working on multidisciplinary teams and an external client. • Develop multidisciplinary synergy in designing disciplines.

These courses were chosen thematically, to address issues pertinent to today's supply chain methods including the need for facility drawing, cost analysis, operations analysis, and comprehensive project design. In AEC 132 and 320, students are introduced to basic drawing and computer aided drawing. These courses prepare students to further understand concepts of facility drawing. In IET 370, students learn operations research techniques and apply those techniques to solve logistics and supply chain problems. They also learn about the transportation and distributions aspects of final products. IET 350 involves the analysis, calculation, and improvement of costs of products. Students had to buy individual components of a typical product and analyze them. Finally, in senior project (IET 400), students work on multi-disciplinary teams and finalize a written report and an oral presentation. Students apply and balance concepts of design for process optimization, assembly, disassembly, cost estimation, and distribution of sample products. They also demonstrate their ability to work on a major real-world engineering problem while working on multi-disciplinary teams and an external client.

Assessment of students learning outcomes

The assessment of students learning recognizes that assessment starts with individual assignments—but broadens the term to encompass the measurement of learning at the course, program, and college levels. This project targets the course level assessment since the implementation of MILL model started a year ago. By the end of next year, the assessment results will show more global and comprehensive measures of cumulative learning at program level. How do we know when students finish a course that they have all the skills and abilities intended for that course? How do we know when a student completes a major that they have learned what is needed to succeed in that field? What abilities, talents, and attitudes do we expect students to have when they complete a general education pattern, and how do we know they have those traits? All these questions are very valid but hard to measure. Following processes were used to measure the students learning outcomes.

1) Create written statements of measurable student learning outcomes.
2) Choose the measuring tool.
3) Set standards for levels of performance on each objective.

4) Identify observable factors that provide the basis for assessing which level of performance has been achieved on each objective.

5) Set benchmarks for successful student, course, program, or degree outcomes, including milestones to gradually move from current performance levels to the benchmark goal.

6) Evaluate student performance, assemble the data, and report the results.

7) Use the results to improve student learning.

These processes apply to designing measurable learning outcomes at the lesson, course, and program level. This series of exercises began at the course level and then expanded to the program level. The learning objectives shown in Table 3 were mapped onto program-level learning outcomes for the implementing institution. The course-level learning objectives were broken down further into descriptions of specific concepts to be learned and competencies to be acquired. Thus, a complete concept map addressing the designated competencies was developed. This constitutes the blueprint for developing assessment items. The corresponding curriculum adaptations were implemented only over a 12 months period. In the 12 months time period three courses were offered as planned. They are AEC 132, AEC 320, and IET 350. An assessment instrument was developed to check students' understanding for these courses. The results of the assessments were analyzed and presented in the following section.

Results and conclusions

Each of the course objectives were mapped with ABET's students learning outcomes for both general and program specific criteria. A sample map of IET 350 course is shown in the following table.

Table 4: IET 350 course objectives mapping with ABET criteria

Course	Title	Course Objectives	General Criteria											Program		Assessment Tools
			a	b	c	d	e	f	g	h	i	j	k	a	b	
IET 350	Industrial Cost Control	1. Define cost components in the engineering designs, operations, products, projects, or systems by following logical manners to develop estimating scheme	1,3	1,3		1,3		1,3		1,3			1,3	1,3	1,3	1. Midterm Exam 2. Final Exam 3. Case Study 4. Class Participation 5. Project
		2. Estimate costs related to product, labor, material, and other components that are converted to finished product and prediction	1,3	1,3		1,3		1,3		1,3		3	1,3	1,3	1,3	
		3. Understand dimensional conversions for international trade	1,3	1,3		1,3		1,3		1,3			1,3	1,3	1,3	
		4. Analyze money transactions of business before the actual spending, balance sheet, income, information, control of cost with aspects of	1,3	1,3		1,3		1,3		1,3			1,3	1,3	1,3	
		5. Understand general estimating methods, advantages and shortcomings	2,3,4	2,3		2,3		2,3		2,3			2,3	2,3	2,3,4	
		6. Predict the dominated project by making choices among engineering alternatives in terms of investment, future revenue and costs	2	2		2		2					2	2	2	
		7. Provide concept about creativity and details for starting a new business or augmenting the opportunity for an existing business	4,5	4,5				4,5				3	4,5	4,5	4,5	
		8. Evaluate the economic context of the enterprise and entrepreneurship activities										3	5	3,5	4,5	

Table 4 shows the specific course objectives and assessment tools used for IET 350 course. General students learning outcomes "a, b, c, …k" and program learning outcomes for IET program "a and b" of ABET are listed as follows.

ABET's General Criteria

For baccalaureate degree programs, these student outcomes must include, but are not limited to, the following learned capabilities:

a. an ability to select and apply the knowledge, techniques, skills, and modern tools of their disciplines to broadly-defined engineering technology activities,

b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies,

c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes,

d. an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives,

e. an ability to function effectively as a member or leader on a technical team,

f. an ability to identify, analyze, and solve broadly-defined engineering technology problems,

g. an ability to communicate effectively regarding broadly-defined engineering technology activities,

h. an understanding of the need for and an ability to engage in self-directed continuing professional development,

i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity,

j. a knowledge of the impact of engineering technology solutions in a societal and global context, and

k. a commitment to quality, timeliness, and continuous improvement.

<u>ABET's Criteria Specific to Industrial Engineering Technology (IET)</u>

    a. graduates must demonstrate the ability to accomplish the integration of systems using appropriate analytical, computational, and application practices and procedures.

    b. graduates at the baccalaureate level must demonstrate the ability to apply knowledge of probability, statistics, engineering economic analysis and cost control, and other technical sciences and specialties necessary in the field of industrial engineering technology.

Pre and post MILL implementation results

Individual course assessment results prior to MILL implementation reveal that all the students learning outcomes were not satisfied for IET 350 course consistently. Table 5 shows the assessment results of IET 350 which was offered in the spring of 2010. In several assessment criteria (highlighted in yellow), the students learning outcomes were not satisfied.

Table 5: Students learning outcomes assessment of IET 350 for spring 2010 semester

IET 350- Industrial Cost Control
Section: G001
Spring 2010
Assessment Methods

1. Midterm Exam
2. Final Exam
3. Case Study
4. Class Participation
5. Group Project

● Process: Do not include I or W or W/P students
● Do not include students that are Not Attending
● Separate findings by program areas
● Translate any grading scales to a 100 point scale
● Target performance is 80% >= 70 on each assessment
● If less than 80%, provide an analysis and action plan

Step 1: List each course by section; list total number of students enrolled

Semester	Spring 2010
Section	Online
Total Enrolled	35

Step 2: Separate enrollments by program area

Program	ACT	BCT	IET	Other
Enrolled by Program	3	18	13	1

Step 3: List assessments for this course and record number of students in each program making >= 70 on assessments

	>=70			
1 Midterm	2	15	13	1
2. Final	3	18	13	1
3. Case Study	3	12	12	1
4. Class Participation	2	7	10	1
5. Group Project	3	15	12	1

Step 4: Calculate percentages by program meeting target performance level of 80% (see underlying formulas)

	ACT	BCT	IET	Other
*	67	83	100	100
	100	100	100	100
**	100	67	92	100
***	67	39	77	100
	100	83	92	100

Step 5: If any percentages (from Step 4 above) are less than 80%, provide an analysis of the problem and action plan to improve
* One out of three students didn't do well in the midterm due to his personal issue
**Some of the BCT students missed 1-2 quizzes by not submitting within the deadline.
*** This assignment was optional and many students didn't attend.

The same assessment was conducted for IET 350 course in the spring of 2011 and found that all students learning outcomes were satisfied 100% of the time. A considerable amount of time was expended examining the differences between pre and post implementation of MILL. One key finding was that the students in IET 350 course in the spring of 2011 were more engaged and had a better understanding of the subject matter. These students were designing the same product in AEC 132 and AEC 320 and participated in hands-on-experience for IET 350 course in the spring of 2011. They were able to relate their past learning in this course and hence were motivated to excel in this class.

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