Use Of Activity-Based Learning Across The Curricula In Mechanical, Manufacturing, and Industrial Engineering Technologies

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Abstract

Modern educational philosophy espouses activity-based learning based on constructivist principles as a means of enhancing student learning and retention of key competencies. Constructivist principles call for assisting learners to build on their own experiences and to use experimentation and problem solving in authentic contexts to acquire new competencies. Further, learners are asked to demonstrate their competence in ways that emulate how the competencies are used in real-world work and life situations. Activity-based learning is also espoused in the new TAC of ABET criteria as one effective method of learning. This paper describes ways in which activity-based learning can be applied across the curriculum in mechanical, manufacturing, and industrial engineering technologies. The examples given can also be adapted to other engineering technology disciplines as well as by many other academic disciplines in a wide variety of educational fields.

Background for the Article

This article is based on work being done by the National Center of Excellence for Advanced Manufacturing Education (NCE/AME) in Dayton, Ohio. The NCE/AME is managed through the Advanced Integrated Manufacturing Center (AIM Center), a partnership between Sinclair Community College and the University of Dayton. The work is supported in part by the National Science Foundation through the Advanced Technological Education (ATE) program.[*]

One major goal of the NCE/AME is to develop novel curriculum materials for the manufacturing engineering technology field that are based on constructivist principles. To this end, a methodology for producing instructional modules has been developed that is activity-based, competency-based, contextual, industry-verified and teamwork-based with assessment embedded at every stage. The module development process has been called the *Module Architecture*©, a term that is in the process of being registered by the AIM Center.

The Module Architecture© has been initially applied to the design of a novel curriculum for a complete associate degree program in manufacturing engineering technology.[1] Because the content of the manufacturing engineering field is highly interdisciplinary, application of the results of this project can easily be introduced in either manufacturing, mechanical, or industrial engineering technologies. For the purposes of this paper the following abbreviations for these three programs are used, MfgET, MET, and IET.

Basic Nature Of Activity-Based Learning And Constructivist Principles

Modern educational philosophy espouses activity-based learning based on constructivist principles as a means of enhancing student learning and retention of key competencies. Constructivist principles call for assisting learners to build on their own experiences and to use experimentation and problem solving in authentic contexts to acquire new competencies. Further, learners are asked to demonstrate their competence in ways that emulate how the competencies are used in real-world work and life situations. [2,3,4,5,6]

Savery and Duffy (1995) [2] outline eight principles of constructivism as follows:

1. Anchor all learning activities to a larger task or problem.
2. Support the learner in developing ownership for the overall problem or task.
3. Design an authentic task.
4. Design the task and the learning environment to reflect the complexity of the environment the learner should be able to function in at the end of the leaning.
5. Give the learner ownership of the process used to develop a solution.
6. Design the learning environment to support and challenge the learner's thinking.
7. Encourage testing ideas against alternative views and alternative contexts.
8. Provide opportunity for and support of reflection on both the content learned and the learning process.

Problem based learning (PBL) is one effective model that is based on constructivist principles. Also called *activity-based learning*, PBL involves engaging the learner in an activity patterned from an authentic task that would be performed by a competent practitioner in the field in which the learner will eventually find a career position.

Authentic Learning Tasks Developed by the NCE/AME

In the work of the NCE/AME, the problem is called an *authentic learning task* or ALT. The ALT is designed to provide an experience in which the learner can acquire a few specific competencies through a process of discovery, experimentation, and generalization. A set of ALTs is combined in an instructional module to enable the learner to acquire a more comprehensive set of competencies. Testing the newly acquired ideas in alternative contexts (Item 7 from the above list) is accomplished by the final part of a module called the *transfer activity*. Here the learners complete a more complex activity in which they are required to apply correctly all of the competencies acquired in the previous ALTs. Figure 1 is a diagram of the Module Architecture©.

Prior to engaging in the authentic learning tasks, learners are guided to identify a variety of contexts in which the competencies they are about to acquire are applied in real-world environments. They are encouraged to offer examples with which they are already familiar so that they can connect their personal experience to the learning task. Examples are cited from a real industrial organization in which the competencies are being applied with world-class effectiveness. This shows the learners the relevance of the activities to their future careers.

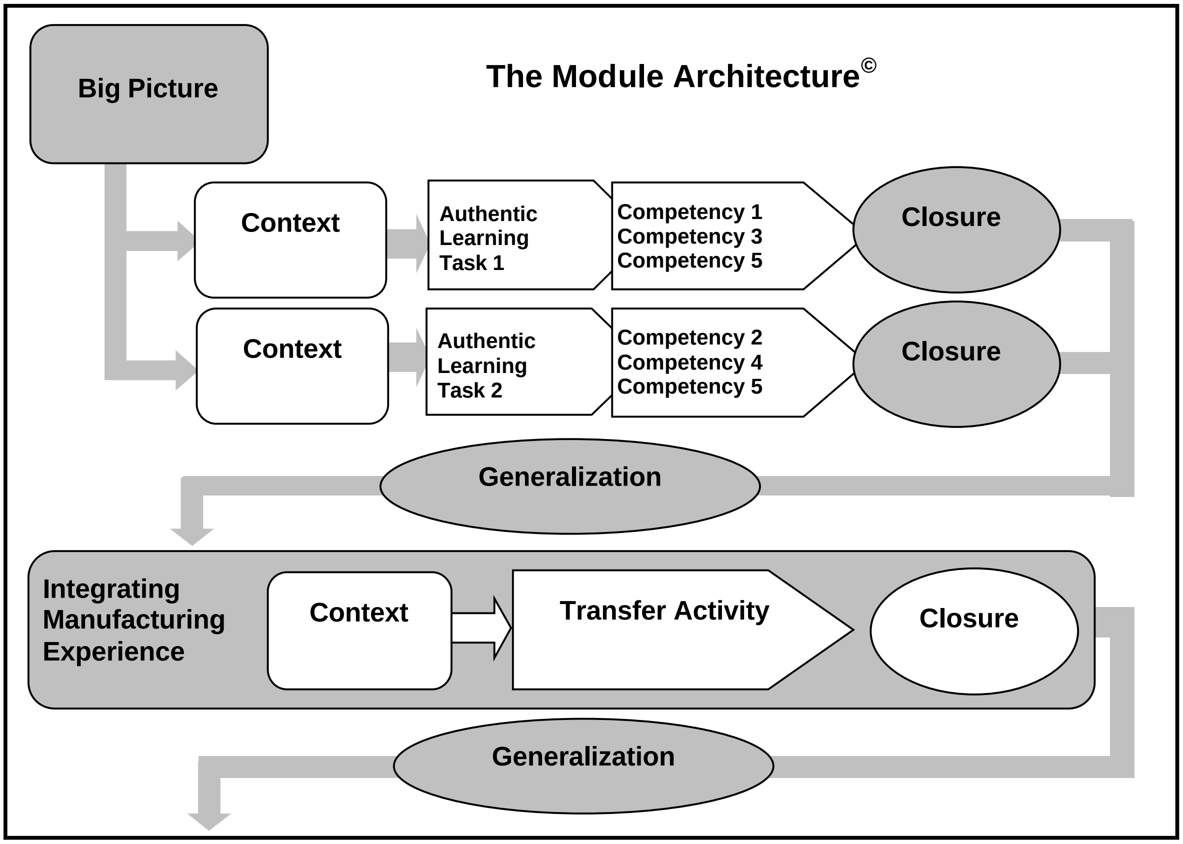

Figure 1

The ALTs typically contain a statement of the competencies to be acquired, a brief overview of the task to be performed, a description of the facilities and materials required, a summary of information resources available to support the task, a definition of the deliverables required from the activity, and a description of the manner by which the learners' performance will be assessed. The activity requires the acquisition of data from experiments or information from pertinent references or external sources. The information and data must be analyzed to determine the underlying principles involved in the activity and to draw conclusions or to make recommendations for action. Learners thus *construct* their learning, building on prior experiences and their newly discovered information. Generalization is aided by engaging in a dialog about how the competencies from the module can be applied in a variety of contexts.

Problem based learning is best applied in collaborative learning groups or teams.[2,5] The conversations among team members allow them to test ideas and to offer critical feedback to others, a key skill that is essential to most engineering technology career paths. The result is the creation of a *community of learners*[5] where a rich variety of viewpoints are applied to the problem and where decision-making and consensus-building skills are learned.

Cobb (1994) [4] identifies another valuable result from the use of constructivist methodologies. Learners not only acquire knowledge of content but also they develop improved facility with the processes of problem identification, experimentation, analysis, and problem solving. Communication skills are also enhanced through interpersonal interactions, informal and formal presentations, and written memorandums and reports.

Problem based learning is best done by having learners engage in multiple activities throughout their curriculum. [2] With each added activity, students become more effective self-directed learners. They become adept at seeing what needs to be done, identifying possible approaches to solving a problem, seeking pertinent information, performing necessary analyses, drawing conclusions, and communicating results. [6]

Alternative Learning Theories

Other learning theories besides constructivism have value for engineering technology education. Ertmer and Newby (1993) [3] describe and compare the critical features of *behaviorism*, *cognitivism*, and *constructivism*.

They state that in behaviorism, learning is accomplished when a proper response is demonstrated following the presentation of a specific environmental stimulus. It can be an effective strategy for recalling facts, defining terms, and performing a specified procedure. These are important parts of education in engineering technology but they tend to be the lower-level skills. Behaviorism is not so effective where higher-level skills, problem solving, and critical thinking are required.

Ertmer and Newby go on to describe cognitive theories that focus on how information is received, organized, stored, and retrieved by the mind. Cognitivism is concerned more with how learners acquire knowledge and not so much with what they do with the knowledge gained. They emphasize that learners must be active participants in the learning process. Knowledge transfer and reasoning ability are enhanced by cognitivism. [3] Useful cognitive tools are analogies, metaphors, outlining, concept mapping, and summaries.

Constructivist theories contend that learners build personal interpretations of the world based on individual experiences and interactions and, therefore, learning should occur in realistic settings through learning tasks that are relevant to the student's lived experience. [3]

There is room for the combined use of all three of these learning theories in engineering technology education. Jonassen (1999) [5] maintains that introductory knowledge acquisition is better supported by behavioral and/or cognitive approaches. As students gain skills, the learning environment should be transitioned to employ constructivist approaches. This use of a variety of approaches can occur within a given course. Some use of constructivism should occur at all levels of a curriculum to help the student to see the relevance of the competencies being acquired. The later part of a curriculum should be designed with progressively greater emphasis on constructivism.

Advantages Of Activity-Based Learning Versus Lecture-Based Teaching

One key concept in educational improvement is that there should be more emphasis on *student learning* as opposed to the *process of teaching*. Research such as that reported above indicates that students learn best in situations in which they are actively engaged in the learning process. Furthermore, particularly in engineering technology programs, students are expected to be able to perform useful tasks immediately upon completion of the program. There is an emphasis on *what students can do* in addition to *what they know*. They are expected to critically analyze problems and generate appropriate solutions with minimal supervision, adapt to changing conditions, and continue to learn new technologies and new techniques.

Much of today's education focuses on the lecture method in which the instructor delivers the subject matter and expects the student to recall it and to be able to repeat it back to the instructor on command. Students are often not actively engaged during lecture classes, either physically or mentally. Tests are often based on the students' ability to recall information or to perform solutions to problems that are precisely stated and for which there is only one correct answer.

Activity based learning built from constructivist principles calls on students to perform authentic tasks that emulate the kinds of work they will be expected to do during their careers. The activities are often ill structured as opposed to being precisely stated. Students must analyze the task, gather information pertinent to the objectives of the problem, clearly state the problem, perform experimentation, generate multiple possible solutions for the problem, evaluate the possible solutions, make decisions about the best course of action, plan for the implementation of the optimum solution, and communicate the final set of recommendations. It is inherent in this process that students must be actively engaged.

Certainly, graduates of engineering technology programs are expected to carry with them a rather large set of competencies and knowledge of fundamental technical concepts. This is often the primary goal for teachers who emphasize "covering content" in lecture courses. Such courses are typically packed with material to the extent that it is difficult for students to assimilate a major part of the concepts. It is charged that long-term retention of knowledge acquired from lecture classes is not good. Studies by Bridges and Hallinger (1992) [7] and by Boud and Feletti (1991) [8] show that students who acquire competencies through problem based learning do as well as students in traditional classes in a variety of disciplines on standard or board qualifying exams and they retain their knowledge longer after the exam. There are added benefits of having gained relevant experiences that can be directly applied in their career positions.

The Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC of ABET) in its new TC2K criteria identifies activity-based learning as one preferred feature of engineering technology programs in Criterion 6 on Assessment. [9]

It has been the experiences of students who have completed the instructional modules developed by the NCE/AME that they do, indeed, acquire the specified competencies and that they are able to apply effectively the knowledge and skills learned to following courses and in their professional careers. [10] In addition, students report that the learning process was more enjoyable than traditional lectures. Minorities and female students performed as well or better than their white male colleagues when using the modules.

Examples Of Activity-Based Learning As Used In The NCE/AME Instructional Modules

A few of the instructional modules developed by the NCE/AME as part of the associate degree program in manufacturing engineering technology are described here to illustrate how activity-based instruction can be integrated within existing courses in the MfgET, MET, and IET programs.

Manufacturing: The complete associate degree program contains nine instructional modules in the Manufacturing Processes and Materials cluster. *Non-Metallic Materials* is one of four modules in this cluster that deal with materials, the others being *Metallic Materials, Heat Treatment/Thermal Processes,* and *Plastics Manufacturing Processes and Materials.*

The competencies that students gain from the *Non-Metallic Materials* module are:

- Define and provide examples of each of the following materials: elastomers, composites, ceramics, abrasives, wood, paper, and food.

- Explain the following concepts as they relate to non-metallic materials: directionality, fatigue, strength-to-weight ratio, ductile-brittle transition, impact resistance, temperature resistance, and electrical conductivity.
- Recognize if/how temperature affects these properties.
- Identify the properties that must be considered when selecting a non-metallic material.
- Describe the processing techniques available for elastomers, composites, ceramics, abrasives, wood, paper, and food.

Teams of students complete six authentic learning tasks (ALTS) as the vehicles for them to acquire these competencies. They are, simply: 1) Wood and Paper, 2) Ceramics, 3) Abrasives, 4) Food, 5) Elastomers, and 6) Composites. In each ALT the students perform a task that facilitates their discovery of the major performance characteristics of the given material. The emphasis is on the activity. However, there is some information transfer through information sheets contained in the module document and from accompanying texts and references. The instructor typically will lead a brief discussion about the main principles involved to ensure that the students are prepared to complete the task successfully.

As they work through an ALT, students generate a set of prescribed deliverables as a record of their accomplishments and as evidence of their competence. Deliverables take many forms with a heavy emphasis on oral and written reports, carefully prepared data sheets from experimentation, analyses of data, and generation of a recommended course of action based on the results of the activity. This emulates the way tasks are completed in a technical career position. The instructor observes the activity itself and evaluates the deliverables submitted. More discussion about assessment is given later in this paper.

Consider the activities in the authentic learning task concerning elastomers in this *Non-Metallic Materials* module. Students are engaged in:

- Measuring and comparing the electrical conductivity of liquid and solid forms of latex
- Measuring the possible elongation that latex can undergo before failure
- Measuring, comparing and contrasting the elongation of latex strips, silicone caulk, and rubber strips cut from a bicycle tube at temperatures near 100°C (212°F), 20°C (68°F), and 0°C (32°F).
- Using the results of this activity to recommend which type of material would be most suitable for use in the manufacture of a new bungee cord.

Following all six ALTS, a *transfer activity* (TA) is completed that requires each team to demonstrate their ability to apply the just-learned competencies in a new and different context. This step is a major part of the constructivist approach and it sets the learning firmly in each student's mind.

In this module, the transfer activity is in the form of an assignment from a supervisor to consider replacing a metallic component of a robotic gripper with some non-metallic material. Each team must do the following:

- Enumerate the functional requirements that the current metallic component satisfies

- Identify several non-metallic materials that could reasonably be considered for this application
- Evaluate each proposed material
- Recommend which material should be used
- Justify the recommendation
- Deliver both a written report and an oral presentation about their activity.

Mechanical: A total of seven modules make up the Design for Manufacturing cluster in which manufacturing engineering technology students acquire competencies that enable them to participate effectively on product development teams. These modules basically represent important features of the mechanical engineering technology field.

Conceptual Design is one module from this cluster that enables students to develop and demonstrate competence in the application of the product realization process (PRP). The competencies are:

- Participate effectively on a Product Development Team.
- Articulate the essential characteristics of a Product Development Team.
- Identify customer needs.
- Derive functional requirements, design requirements, and design criteria based on customer requirements.
- Develop conceptual designs based on functional requirements, design requirements, and design criteria.
- Present conceptual designs in the form of sketches and written narration that show how specifications have been met.
- Identify appropriate manufacturing processes for a particular design.
- Perform a standard decision analysis.
- Present a final product design, including its manufacturing processes, to a design process review committee.
- Respond effectively to a design review committee's questions and constructive criticism relating to conceptual design.
- Describe the Design Failure Mode and Effects Analysis (DFMEA) process.
- Recognize a standard DFMEA form and explain how it is completed.
- Describe the Process Failure Mode and Effects Analysis (PFMEA) process.
- Recognize a standard PFMEA form and explain how it is completed.

The authentic learning tasks in this module guide teams of students through each part of the set of competencies listed above using a simple product selected from those suggested in the module, assigned by the instructor, or generated by the students themselves.

The transfer activity for this module is the application of the competencies to an assignment to modify the fingers of a robotic gripper to meet a special need of a particular customer.

This module is especially effective when the teams include both mechanical and manufacturing engineering technology students but is quite strong with any group who needs to understand the product realization process.

Industrial: Nine modules make up the Production and Inventory Control (PIC) cluster in the associate degree program for the manufacturing engineering technology program. PIC is a field that is solidly within the purview of industrial engineering technology but that is also important for the manufacturing professional.

Process Flow and Lead Time Reduction is a key module within the PIC cluster. Students who bring a good foundation in the principles of just-in-time manufacturing acquire the following competencies:

- Describe the importance of effective work flow and short lead times in manufacturing operations.
- Use process flow and lead time analysis and reduction techniques.
- Identify and eliminate waste in manufacturing systems.
- Analyze setup and changeover procedures.
- Design processes for rapid setups and changeovers.
- Use the "Seven Deadly Sins of Waste" model to eliminate waste in a manufacturing process.

Teams of students acquire these competencies as they complete four authentic learning tasks, briefly described below.

1. Balancing the flow of a process is accomplished by teams of students as they analyze a given process, the overhaul of an aircraft engine, and prepare a revised flowchart that improves process flow and reduces lead time.
2. Students identify the essential characteristics of "world-class manufacturing" by searching for and analyzing documents from existing literature, including the Internet, technological periodicals, and books, and information from professional organizations. Results are presented in an oral presentation and a written report.
3. Students prepare a detailed, structured process plan that involves a changeover activity. The activity is one that all students can relate to, the preparation of breakfast (frying and serving and egg) followed by changing the work setup to prepare sandwiches for lunch. This scenario for a diner contains all the elements of process flow and lead time reduction that would be seen in a factory operation in virtually any kind of industry.
4. Teams of students learn the methods of eliminating waste in a process as they develop plans for improving the delivery of paper from a central warehousing facility to a group of 25 buildings on a college campus. The concepts learned can be applied to a manufacturing system or to virtually any process requiring materials.

Transfer Activity: Students apply the competencies again in the transfer activity. Two different versions of a robotic gripper are to be assembled in the same facility. Student teams design the process for assembling each gripper including the changeover from one to the other.

An Integrating Manufacturing Experience

Students should view their educational experience as an integrated whole, not just a series of unrelated academic exercises. They should see the inter-relatedness among all modules and all courses in their program. Furthermore, they should understand how each gives them skills and knowledge that is relevant to their future career path. The instructional materials developed by the NCE/AME accomplish this goal through a unique pedagogical device called the *integrating manufacturing experience.*

This concept is illustrated in the brief overviews for the three instructional modules given above. Note that each module ends with students completing a transfer activity, each of which related to a robotic gripper. Sometimes called an end-effector, the gripper attaches to the end of the arm of a robot and it grasps objects for transporting them to another location. To facilitate the use of robotic grippers throughout the program, and to give the concept a more robust nature, the NCE/AME team created a hypothetical company called *Robotic Grippers, Inc.* [+] that designs and produces a line of pneumatically operated robotic grippers. Descriptions of the company, its facilities, its markets, and its product lines have been developed and provided to module authors. Prototypes of the grippers and drawings of their components are available to those adopting the modules for use.

Implementation of Activity-Based Learning

This paper advocates the increased use of activity-based learning techniques in engineering technology programs and across the curricula. Educators and learners have described the advantages in terms of more effective learning and greater long-term retention. [7, 8, 10] Implementation can take place in many ways, all of which require significant change for the faculty members responsible for delivering the instruction. Issues related to implementation are addressed now regarding faculty development, availability of suitable instructional materials, organization of courses and programs, assessment of student competency, and accreditation.

Faculty Development: Most engineering technology education today is done in the traditional lecture manner. Instructors create (or are given) a syllabus, a textbook is specified, and the content is organized into set blocks that can be "covered" in typically 50 to 75 minutes per class session. Students sit in the classroom, listen to the lecture, and take notes. They then go to their homes and study or work problems similar to those the instructor demonstrated so they can repeat the process on a timed test.

Good instructors engage students in discussion about the material in an attempt to enhance the students' state of active learning as espoused by cognitive learning theory. Often students avoid such opportunities out of shyness or fear of making an error or showing that they are not prepared for the session. But if they persist and expend a reasonable effort, they may score sufficiently well on the tests. And after spending a specified number of hours in class over a specified number of weeks, they are awarded a specified number of credits. But have they really learned? Will they be able to apply the skills they have learned in new and different contexts in the future?

The instructor's role in the scenario described above is to "deliver instruction." It does not necessarily require the students to do much more than pay attention, and the result is often that their minds wander and important concepts are missed. Many students do not learn well by auditory means. Activity-based learning tends to overcome these age-old problems of education. But the consequence is that instructors must change the way they conduct their classes. This is often difficult because of ingrained habits or convictions. Most instructors succeeded in similar lecture-based environments during their own schooling and expect their current students to do so as well. Those who do not are branded as being non-diligent or not capable of learning the material. The real answer may be that another mode of instruction that puts the learner (instead of the instructor) at the center of the activity will produce better learning for a wider variety of students.

To implement activity-based learning requires the instructor to plan carefully for each session so that students can take on robust tasks that are specially designed to help them acquire a specific set of competencies. The instructor becomes a facilitator of learning rather than a deliverer of instruction. A phrase that describes this has now become a cliché in education is:

> *The instructor must stop being a sage on the stage*
> *and instead become the guide on the side.*

There is risk in doing so because the instructor does not control every part of the time while the students are working on the assigned task. Even in a well-planned activity, surprise events may take place, students may exhibit difficulties that are not predictable, and it may be difficult to control the time required to complete the activity. Instructors must have a command of the subject matter that allows them to be agile in dealing with such situations. Another view of this situation is that instructors should not always directly answer a student's question but should encourage the student to explore for the answer on their own. This practice leads the student to become a more independent learner and that will serve her or him well in the future. Indeed, that is a skill that employers seek.

Availability of Instructional Materials: This is a real issue because most text material available today is designed to support lecture-based courses. Some activity-based, modular materials are being developed through projects funded by external grants from organizations such as the National Science Foundation. The NSF Division of Undergraduate Education manages the Advanced Technological Education (ATE) program and many projects and centers are producing instructional materials using varying forms of activity-based pedagogy.

The NCE/AME in Dayton, Ohio that has been mentioned several times in this paper is a national center supported in part by the ATE program. A novel module development process is being used to produce instructional modules in nine clusters of subject matter pertinent to manufacturing engineering technology. [1] As illustrated before, some modules are also applicable to mechanical and industrial engineering technologies. Many are appropriate to virtually any technical discipline. The clusters are:

Manufacturing Processes and Materials Design for Manufacturing Production and Inventory Control Quality Management Manufacturing Systems and Automation Enterprise Integration	Mathematics Science Humanities, Communications and Teamwork

In addition to producing complete modules, the NCE/AME offers support for institutions and programs that desire to move toward modular, activity-based, competency-based instruction. Assistance for departments or individual faculty members to develop their own modules or authentic learning tasks is also available through the use of a set of development kits. Descriptions of these products and services are available at www.aimcenter.org.

Organizational Issues: Organization of the activities within the college schedule is also affected by a move toward modular, activity-based, competency-based instruction. Successful activities often require more than the traditional 50-75 minute class times to complete. An ideal solution would be to permit instructors to gather teams of students who are ready for a particular instructional module at any time and spend whatever time is required to complete the activity. Few, if any, colleges are currently organized for this approach. Perhaps they will move in that direction in the future. In the meantime, one solution is to rethink the lecture-laboratory concept that is prevalent in engineering technology education and to blend the time allocated to the course so that the activities can be completed in longer blocks. As needed, the instructor can engage students in dialog about new concepts they need to complete the task at hand. Such just-in-time learning has advantages in that the students are ready to learn the concepts because they see the immediate applicability for it.

This type of instructional organization would work best if the curriculum were broken into smaller units or modules of instruction based on a specific set of competencies to be acquired rather than on an arbitrary amount of time as we do with traditional courses on the quarter or semester system. Modules could be started whenever there is a critical number of students ready to learn and a facilitator available to manage the module. The ramifications of this approach are many. Colleges would have to discontinue standard terms. The accounting for credits would turn from being time-based to being competency based and would require registrars to radically change their student record systems. Scheduling large numbers of students through such an environment would take different logistical and counseling skills. Despite these difficulties, there is still value in moving in this direction of more flexible educational programs.

In the near term, a more practical implementation of activity-based learning approaches is to embed such instructional modules within traditional courses. This would permit instructors to blend the familiar lecture format for transferring basic information with the authentic learning tasks as described earlier in this paper. Or, two or three activity-based modules may be combined in series within the traditional time allocated for a course. When complete modules may not be appropriate for inclusion in a course, individual authentic learning tasks (ALTs) may be inserted that can be completed in shorter spans of time.

Assessment of Student Competency: Evaluation of student performance using traditional testing is often not appropriate for activity-based instruction. Students should be evaluated on the basis of *what they do* and *the deliverables they produce* rather than on rote memory or rigidly applying a given methodology. The authentic learning tasks call for students to plan and implement experiments, operate equipment and instrumentation, create designs, generate process plans, analyze data, draw conclusions, make decisions, justify recommendations, write reports, give oral presentations, and produce numerous other kinds of deliverables that demonstrate their competence. Assessment of the students' competence, then, should be matched with the kind of deliverables produced.

Just as the tasks completed by students are *authentic*, the assessment techniques used to gather evidence of student competence should also be authentic. A variety of assessment methods should be used. One very good source for ideas for alternative assessment is listed as Reference 11. Angelo and Cross describe 50 different techniques that can be applied in the classroom. Many of their ideas have been adapted for use in the instructional modules produced by the NCE/AME. Each ALT and the Transfer Activity have assessment methods embedded that are keyed from the competencies the students are expected to demonstrate through the deliverables produced.

An often-used technique is to establish a rubric that describes the nature of competent performance for a task. The instructor then evaluates each student's work against this rubric. Those meeting the required standard are rated as *competent*. Those who excel beyond the basic requirements are rated as *exceeding expectations.* Those who are deficient on one or more factors in the rubric are rated as *needs improvement* and they must repeat certain deliverables until the quality meets the competent standard.

Accreditation Issues: With the advent of outcomes based accreditation criteria, such as TC2K now being promulgated by TAC of ABET, the use of novel activity-based approaches as described in this paper should become very desirable. [9] Activity-based instruction inherently calls for expected outcomes to be defined up front in the form of competency statements. Then the assessment and evaluation techniques just described provide a built-in means of proving that each student has acquired the expected level of competence. Indeed the TC2K document identifies the use of activity-based methods as one of the preferred approaches to instruction.

The nature of the NCE/AME modules also ties in well with the primary elements of *Criterion 1. Students and Graduates* from TC2K. The complete list of items often referred to as the "a. through k. list" can be found in Reference 9.

Briefly stated, the activity-based approach used in the NCE/AME modules inherently demonstrates (a) mastery of knowledge and skills, (b) ability to apply knowledge, (c) ability to conduct and analyze experiments, (d) ability to design systems and components, (e) ability to function effectively on teams, (f) ability to solve problems, (g) ability to communicate effectively, (h) ability to engage in lifelong learning, (i) ability to act professionally (j) with respect for diversity, and (k) a commitment to quality, timeliness, and continuous improvement.

Application of the Methodology to Other Disciplines

While the focus of this article is on the manufacturing, mechanical, and industrial engineering technologies, it should be mentioned that the Module Architecture© developed by the NCE/AME can be applied and adapted to virtually any education program or industrial training exercise in which participants are expected to acquire and demonstrate a specific set of competencies that are expected in a job situation.

Indeed, modules have been produced from a wide variety of fields as indicated in the list of clusters earlier in this paper. In addition to the technical clusters, modules have been developed in mathematics, science, communications, and teamwork. The enterprise integration cluster includes elements of business management such as customer satisfaction, financial management, and supply chain management.

Instructional modules have been completed for industrial clients that are being used to enhance the ability of customers to use effectively the features of high-technology equipment. A module called *Tools for the Future* has been used by numerous companies to enhance employee performance by implementing the principles espoused by Eli Goldratt in *The Goal* and *Theory of Constraints* and by Stephen Covey in *Seven Habits of Highly Effective People.*

Conclusion

This paper has discussed the educational value of activity-based instruction built on constructivist principles for mechanical, manufacturing, and industrial engineering technology programs and for many other educational enterprises. The novel pedagogy employing activity-based instruction that has been developed by the National Center of Excellence for Advanced Manufacturing Education has been used as an example. It is hoped that readers will move toward implementation of these techniques as part of a strategy to continuously improve engineering technology education by focusing on the learners in our classrooms. The result should be an even stronger cadre of high-performing graduates for U.S. industries.

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[+] The concept of *Robotic Grippers, Inc.* is based on a project developed by Professor Thomas E. Endres of the Mechanical and Aerospace Engineering department at the University of Dayton.

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