Re-Engineering Technician Education For The New Millennium

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Abstract

The U.S. Accreditation Board for Engineering and Technology (ABET) Engineering Criteria 2000[1] (EC-2000) requires that graduates of two-and four-year engineering technology (ET) programs demonstrate proficiency in mathematics, science, and engineering, be able to work in multidisciplinary teams, communicate effectively, be sensitive to the social and ethical issues related to the engineering profession, and develop the capacity for lifelong learning. While many four-year colleges and universities have embraced EC-2000 and have restructured their curricula and instructional methodology accordingly, the limited time available in two-year engineering technology curricula presents a unique challenge to associate degree-granting institutions – preparing learners with the appropriate knowledge, skills, and attitudes needed to succeed in 21st century workplace. What is needed is a more efficient and effective approach to engineering technician education, one that focuses on the development of learner proficiency, the ability to skillfully apply knowledge in solving real-world problems. To this end, we draw upon the adult and experiential learning literature to create a pedagogical framework for restructuring engineering technician education. Using an interdisciplinary systems engineering approach grounded in active learning, real-world problem solving, and metacognitive development, we present key strategies for developing and enhancing learner proficiency in engineering technician education.

Introduction

Engineering technicians play a critical role in the high tech industries that drives this nation's economy. Working side-by-side with engineers and scientists, engineering technicians are the "hands-on" people, responsible for building, testing and troubleshooting simple devices and components to complex integrated systems. Engineering technicians design experiments, build prototypes, analyze and interpret data, and present experimental results to peers, supervisors and customers. They are required to work individually as well as in interdisciplinary teams, interface with vendors, and contribute to process efficiency in manufacturing and production environments. Given the breadth of knowledge and skills required of the engineering technician, it is ironic that most two-year engineering technician programs are still structured using a discipline-specific educational model (e.g., electrical, mechanical, manufacturing, etc), taught using an instructor-led methodology that hasn't changed in decades.

Critics of engineering technician education[2, 3] argue that educational programs focus too much on the transmittal of information through static lecture-discussion formats and routine laboratory experiences. This approach to education often results in graduates who do not have a full range of important employability skills and competencies needed in business and industry, such as the ability to apply knowledge skillfully to problems of practice, communicate effectively, work as members of a team, and engage in lifelong learning. As a result, engineering technicians often enter the workforce inadequately prepared to adapt to the complex and ever-changing demands the high-tech workplace.

One of the underlying problems with engineering technician education is that while ET faculty may be highly trained experts in their own disciplines, most have had little or no formal training in education[4]. Whereas much progress has been made over the past decade in upgrading the technical skills of faculty through programs such as the National Science Foundation Advanced Technology Education program (NSF-ATE) and others, little attention has been given to the pedagogical methods used to teach these skills to students. Like their predecessors, ET faculty often resort to an instructor-centered approach in their teaching whereby they attempt to "fill" students with knowledge rather than facilitate student learning. In short, they "teach the way they were taught" [5], lecturing, developing assignments and tests, and assigning grades. Students move through a standard sequence of self-contained courses taught in isolation where they learn to solve problems within the narrow context of individual courses[6]. Laboratory courses are often taught using a "cookbook" approach, not affording students sufficient opportunity for critical thinking and synthesis of knowledge; connecting what they have learned to prior knowledge or experience and applying what they have learned in new applications and/or novel situations. Upon completion of core coursework, students are often expected to synthesize the knowledge gained in each course completing a capstone-type project, an approach antithetical to way people really learn. As a result, learners often learn content with little or no regard for the world in which the knowledge is to be applied. This approach is analogous to having all of the required building materials delivered to construction site but having no blueprint to work from – how does it all fit together?

The goal of engineering technician education should not be limited to the transfer of knowledge from instructor to student, but more importantly the development of proficient individuals; individuals who have a well-organized knowledge base and skills set that they can apply to solve real-world problems and who are ready to learn and adapt as technology changes[7]. Instruction should advance learners along an educational continuum that transforms dependent learners, those who rely on the instructor as the sole source for information, to independent learners, those capable of identifying gaps in their own knowledge and skills, and who exercise the self-regulation needed to seek out the resources needed fill those gaps[8, 9] (i.e., metacognitive learners). Instructor-led methods, unfortunately, provide little opportunity for guided inquiry, collaborative learning, and real-world problem solving - strategies shown to facilitate the development of proficiency, the skilled application of knowledge[10].

What is needed is a fundamental restructuring of engineering technician education—an integration of content and pedagogy that fosters the development of proficiency by actively engaging students in individual and collaborative problem-solving, analysis, synthesis, critical thinking, reasoning, and applying knowledge to real-world situations[2, 3]. New instructional strategies must be employed that emphasize practical learning, and require that students demonstrate the proficiency in science, mathematics and engineering fundamentals, communication, multidisciplinary teamwork, lifelong learning skills, and awareness of social and ethical considerations associated with the engineering profession[11] –the basis of EC-2000.

A course of action

In 1992, engineering faculty at Drexel University[12] was presented with the challenge of revamping their engineering curricula to address the "would be" requirements of ABET EC-2000. Following a traditional approach of developing a long sequence of individual courses the faculty felt would address the educational goals and objectives set forth, they soon realized that time constraints would not permit such a sequence; a new approach was needed. What they came up with was an integrated approach to engineering education coined E^4 (An Enhanced Educational Experience for Engineering Students). Fromm[12] described the E^4 approach as a joint venture between mathematics, science, engineering, and humanities faculty, teamed in planning and teaching these topics with interwoven connections and engineering context, with an increased emphasis on experiential learning, interdisciplinary teamwork, and an "engineering upfront" philosophy (p. 114). In short, Drexel faculty applied an integrated systems methodology to engineering education, a holistic approach centered on engineering design, whereby each course (and each topic) is learned in context and as an integral part of a whole. As a result of the E^4 program, Drexel University reported a 50% increase in student retention for the first graduating class that completed the experimental program as well as improved problem solving, negotiation, and critical integration skills.

The E^4 approach taken by Drexel University demonstrated that positive learning outcomes are achievable by applying an integrated systems-level approach to engineering education in a four-year program. The question arises, however, as to whether a similar approach could be applied in a two-year engineering technician program. While enrollment in most four-year engineering programs consists of mainly traditional college-aged students (18-25 years), two-year engineering technician programs most often reside within community colleges where the average student age is 25 to 30+ years. Many of these students work full time, have family obligations, and have been away from school for several years. Some have been downsized, displaced, or have had their jobs outsourced and need retooling. For many, the common denominator is time – they need to acquire new skills and get back into the workforce as quickly as possible. They are adult learners, bringing to the classroom a wealth of experience, and while it may or may not be related to the field of study, it provides a foundation upon which to build new knowledge, and a unique perspective from which they view the world. The challenge for ET faculty is providing students with an optimal balance of core academic knowledge needed to satisfy general education requirements and transferability, and discipline-specific technical skills needed to be marketable upon graduation. Given these constraints, we looked to the adult and experiential learning literature for research to guide the development of a pedagogical framework for enhancing and accelerating learner proficiency in two-year technician education.

In their recent publication "Effectiveness and Efficiency in High Education for Adults", Keeton, Sheckley, and Griggs[13] outline eight key principles, grounded in empirical research, for achieving effectiveness and efficiency in learning that focus specifically on the development of adult learner proficiency. Keeton et al. maintain that proficiency can be achieved when learners are presented with clear learning goals and objectives and a clear path to attainment, a rich body of experience centered on solving genuine real-world problems, opportunities to reflect on their learning both individually and with peers, timely and constructive feedback, and an environment that supports and encourages inquiry. Equally, in their seminal publication, "How People Learn", Bransford[8] et al. argue that individuals learn best when their preconceptions regarding a particular subject are drawn out and engaged, when they are provided with a deep foundation of factual knowledge developed and organized in the context of a conceptual framework, and by developing the metacognitive skills needed to self-regulate their own learning. Applying these key principles, in the following paragraphs we present a pedagogical framework for transforming engineering technician education from a passive instructor-led approach to an active learner-centered approach focused on developing learner proficiency and the skills needed to adapt to the ever-changing demands of 21st century workplace.

Re-engineering engineering technician education

Re-engineering engineering technician education requires that faculty: (1) recognize a need for new and improved instructional approaches; (2) change their mental model - their way of thinking about teaching and learning; and (3) change their practice – the design, evaluation, and delivery of instruction. In developing a model for reforming engineering technician education, we acknowledge that embracing change is sometimes difficult for faculty given the multitude academic and professional activities characteristic of technical education (i.e., keeping up-to-date with latest technology, committees & advisory boards, course overloads, etc.). We also recognize the administrative challenges to restructuring curricula given the complex nature of the curriculum approval process at many institutions. With this in mind, we focus our model on strategies that can be applied within existing curriculum frameworks; methods that have been shown to produce real results in improving learner skills, knowledge, attitudes, and taken as a whole, learner proficiency.

As a first step in re-engineering engineering technician education, we recommend that ET faculty break away from the traditional technician education model of teaching individual content-specific courses, those courses focused on a single topic and taught in isolation from other courses, and adopt a more “holistic” interdisciplinary systems-level approach to technician education. Cotter[14], who contends that when students view the material they are learning in the context of a complete system they are better able to make connections to other courses and other disciplines, supports this approach. Moreover, Keeton[13] et al. argue that solving genuine real-world problems as a focal point of inquiry serves as a catalyst for learning and not only accelerates learning, but also increases learner motivation.

In many electrical engineering technology curricula, students begin their first semester with a series of introductory courses (e.g., DC electric circuits, computer applications, CAD, etc.). These courses are often taught by individual instructors as stand-alone courses; isolated from other instructors, courses, as well as the labs in which the course content is to be applied. Upon successful completion of these courses, students are allowed to continue on to more advanced courses, again taught in isolation; each course building on the previous set of courses in a predetermined sequence intended to provide students with the knowledge and skills needed to, in most cases, complete some type of capstone project in their last semester. The problem with this approach, however, is that the bulk of material covered in the curricula is taught without an understanding of the application or context in which the material is ultimately to be applied. As a result, students learn technical content in small chunks, using a ‘bottom-up’ or ‘component-level’ approach without the benefit of seeing the ‘big picture’; how all of the pieces fit together to form a complete system. As in the E^4 approach developed by Drexel University, subject matter at the two-year engineering technician level should be introduced to students as an integral piece of a larger system; team-taught by faculty from multiple disciplines whose expertise is appropriate for the specific piece of the system being represented. The key here is to provide students up front with a "bird's eye view" of where, how, and why the topic in which they are learning fits into the grand scheme of things – to put into perspective not only the importance of the particular topic of which they are currently focused, but the impact and interrelatedness of the topic within the context of the complete system. This line of "systems" thinking can be applied not only to a particular topic within a course, but also to the course itself as well as an entire curriculum or program.

When applying a systems approach to education, it is important to provide students with clear learning goals and objects as well as a clear path to their attainment. Keeton[13] et al. argue that early and ongoing clarification of learning goals and a clear path to achieving those goals is critical to learning. Furthermore, frequent and ongoing assessment of students' knowledge and skills requiring successful demonstration of core competencies (i.e., learning objectives), evaluated in the context of a real-world application, and coupled with constructive feedback will help students hone their skills and adapt their knowledge to new situations. For example, course syllabi typically include a list of learning objectives upon which students' performance will be based. The purpose for these learning objectives, however, is not often clear to students (e.g., Why is this material important to know, how does it apply in the real world, and how will my progress be evaluated?). Learning objectives in an electric circuits class, for example, may state, "Upon completion of this course, students will be able to:" followed by a list of items such as "measure voltage in a series circuit", or "calculate current in a parallel circuit." While learning to measure voltage and current are important skills to learn in an electric circuits class, they arguably would have more meaning to the student if presented in the context of a complete system (e.g., What effect does a short circuited load have on the output current and voltage of a power supply? Does a motor control circuit provide enough current to run a motor under varying load conditions? How would you determine whether or not a particular circuit performs according to system specifications?). In many cases students simply go through the motions; they complete their homework, take tests, demonstrate the skills required to pass the course, and then move on to the next level without ever knowing the context in which their skills are to be applied. If students are presented with the same learning objectives at the beginning of the course, but in the context of a real-world application such as the design of a simple power supply or electronic control system, they can be made to understand the importance of those learning objectives in relation to a larger system. The learning will take on real meaning, and as a result, students will be better able to apply their knowledge to similar future real-world applications.

Adopting a systems-level approach to engineering technician education is a natural catalyst for helping faculty move towards a more interdisciplinary curriculum. For example, when presenting students in an electric circuits course with specific systems-level applications (e.g., an industrial robot), other aspects of the system such as motor control software, printed circuit-board fabrication, power and thermal requirements, position sensing, manufacturing environment, as well as societal ramifications of the technology can be introduced; team-taught by other instructors or guest lecturers whose specific area of expertise is more appropriate.

In developing a systems approach to technician education, it is essential that industry play an integral role in developing curriculum content, learning objectives, real-world problems scenarios, and assessment criteria for learning outcomes. Industry involvement in the curriculum development process not only adds credibility to the curriculum by ensuring technical relevancy of content, but also contributes to the development of proficiency by grounding learning in the real-world application of knowledge. The use of industry field trips early on in a curriculum can also provide a powerful and motivating learning experience for students as well as faculty by providing a glimpse of the context in which specific skills, knowledge, and attitudes will be applied. By adopting a systems-level approach to a single course, a series of interrelated courses, or ideally an entire curriculum, learners will be better able to apply their knowledge to solve problems across disciplines, but more importantly, adapt to change; the hallmark of lifelong learning.

Apply active learning strategies
Adopting a systems-level approach to engineering technician education is an integral piece of the puzzle in achieving learner proficiency by creating a framework or "playing field" for instruction and learning. How an instructor engages his or her students, on the other hand, can have an even more dramatic impact on their learning. Researchers[8, 13, 15] agree that active learning, learning that involves hands-on experience, problem solving exercises, reflection, formulating generalizations, applying knowledge to new situations, and providing critical feedback that actively engages students in constructing, organizing, and experimenting with a rich knowledge base, improves learning and enhances learner proficiency. Keeton[13] et al. cite a study conducted by Van Eynde and Spencer[16] in which researchers compared learning outcomes for students in a management class taught using lecture-based methods versus active learning (or experiential) methods. In comparison to the lecture-based group, the researchers reported an improvement of one standard deviation for the active learning group with regard to long-term memory and use of concepts over time. Similarly, in a study of over 6000 students enrolled in an introductory physics class, Hake[17] found that students who engaged in active learning scored two standard deviations (almost two times) higher on measures of conceptual understanding of Newtonian mechanics than did students in a traditional lecture-based course. It is clear from these studies that when students are actively involved in their own learning, both understanding and retention of concepts are greatly enhanced, the underpinnings of proficiency development.

Keeton[13] et al. argue, however, that active engagement in the learning process alone does not yield new knowledge unless it is actively reflected upon. Keeton[13] et al. cite numerous studies that show that specific reflective activities such as the exploration of alternative solutions to problems, connecting content to real-world problems, caucusing with others, case analysis, and debriefing with others are critical to the development of proficiency. In one study cited by Keeton et al., a physics class at a large university was restructured in a way that shortened the amount of lecture time, providing more time for active engagement in the learning process through the use of computer simulations and hands-on group work. Within the context of the same lecture-based classroom, students were allocated additional time to interact with one another to discuss problems, conduct group experiments, and share results with the class. As of result of the course restructuring, researchers reported a significant increase in student satisfaction as well as learning outcomes over prior courses.

The implications of active learning on engineering technician education are clear. If our efforts to achieve proficiency among graduates are to be realized, we must embrace an active learning approach to engineering education. Within the constructs of the interdisciplinary systems approach to engineering technician education presented earlier, engineering technology faculty can facilitate active learning in a variety of ways. While some instructors may be initially reluctant to change the way they teach, minor adjustments in classroom strategy can yield substantial results. For example, by simply pausing periodically during the course of a 45-minute lecture to allow students to reflect on their learning, both on an individual and/or group level, Ruhl, Hughes and Schloss[18] showed significant improvements in both short-term and long-term recall.

Engaging in active reflection may also elicit misconceptions regarding students' understanding about the particular topic. According to Bransford[8] et al., if a learner's "initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purpose of a test but revert their preconceptions outside the classroom" (p. 10). Implicit in this approach is the facilitation of collaborative learning. By allowing small groups of students to openly reflect on a particular topic, multiple views and perspectives are melded together to forge or construct new knowledge, the hallmark of collaborative learning – the essence of teamwork. Additional research cited by Massa[19] et al. shows that collaborative learning results in improved learner involvement with coursework, more engagement in the learning process, and is more effective than traditional methods in promoting learning and achievement[20, 21, 22].

One form of active learning is experiential learning, described as the process of creating knowledge whereby new experiences are integrated into prior experience and transformed into relevant, durable and retrievable knowledge that can be applied to problems of practice[10, 23]. In his landmark publication, "Experiential Learning – Experience as a Source for Learning and Development", Kolb[23] asserts, "Learning is the process whereby experience is transformed into knowledge" (p. 38). Kolb[23] described the process of learning as a four-phase repetitive cycle whereby experience is transformed into knowledge. Phase one involves taking in new information through *concrete experience* (i.e., learning by experience). Phase two, *reflective observation,* involves linking new experience to prior experience (i.e., learning by reflecting). This leads to phase three, *abstract conceptualization*, whereby the experience is integrated with existing knowledge to form a new mental model for the experience (i.e., learning by thinking). Phase four, *active experimentation*, involves actively applying the new knowledge to test comprehension (i.e., learning by doing), which lead to new concrete experience. The process then repeats itself. While individual learning style preferences may vary among students, researchers[23, 29] agree that providing learners with experiences that engage them in all four modes of learning (learning around the cycle) is more likely to produce more balanced learners, learners who are capable to applying knowledge across a broad range of situations. Instructional activities that can facilitate learning around the cycle include providing experimental demonstrations, engaging in theoretical analysis, solving closed- and open-ended problems, generating alternative solutions, developing analogies, having students design and test laboratory experiments to validate concepts, and engaging in collaborative problem solving – all examples of active learning.

Research on experiential learning[24, 25, 26] shows that in comparison to lecture-based methods, instruction based on experiential methods not only improve academic performance but is also more effective in enhancing students' ability to transfer their knowledge to new situations. Research on transfer of training[27, 28] shows that while some gains in knowledge can be made through traditional lecture-based classroom instruction, only 10-20% of what is learned in the classroom is ever applied outside the classroom. In contrast, over 70% of what is learned using experiential methods is likely to be applied outside the classroom. Given that engineering technicians are the "hands-on" side of an engineering team, it is imperative that the sufficient real-world experiences be made available to students to provide them the vehicle for transforming classroom content into practical knowledge that can applied in real-world situations.

One of the misconceptions about experiential learning is that students must be provided with theoretical instruction *prior* to engaging in hands-on activities. As is often the case, instructors introduce students to a new topic through abstract lectures and derivations that bear little or no resemblance to the real world application for which the subject matter was intended. Upon receiving an ample instruction on the underlying principles relating to the particular subject matter, students conduct "cookbook" type laboratory experiments intended to validate the principles taught in class. In stark contrast, proponents of experiential learning[30, 31, 32] maintain that 'doing precedes understanding' arguing that hands-on experience should precede theoretical instruction for deep learning to occur. From a practical standpoint, while students do require a rudimentary understanding of the subject matter to be learned in order to frame their thinking and understanding, theoretical instruction must be integrated with concrete experience from the beginning in a way that reinforces the experience, and not the contrary. Consistent with a systems-level approach to engineering technician education, students should be provided with concrete experience with new concept or application, whether through direct hands-on experimentation or demonstrations, *before* engaging in an in-depth discussion on the theoretical underpinnings. As an example, consider trying to explain the sensation of a roller coaster to someone who has never ridden one by applying Newtonian physics and calculating g-force – it's just not the same. By providing concrete experience before engaging in in-depth theoretical analysis, students will be better able to connect abstract theory to something that is real and tangible, and as a result, will be able to create a more durable mental model for the experience that can be further expanded and built upon through subsequent experiences.

Develop students' metacognitive ability

Metacognition has been identified as a key factor that influences an individual's ability to engage in lifelong learning (Bransford[8] et al.). Metacognition is defined as the ability to reflect, control and understand, in a self-aware mode, one's own learning and cognition[9]. In short, metacognition involves "thinking about thinking." While cognitive ability deals with specific learning strategies, metacognition deals with knowledge about one's self as a learner, the task at hand, and the most effective learning strategies for a particular situation (i.e., metacognitive knowledge), as well as how learning is monitored, organized, and reflected upon as the process continues[9, 33] (i.e., self-regulation). Researchers[34, 35] argue that metacognitive learners are more strategic in their learning and perform better than learners who do not employ metacognitive processes. Metacognitive ability is responsible for how individuals plan, sequence, and monitor their learning in a way that directly improves performance[9]. Bransford[8] et al. cite numerous research studies that have shown that teaching students metacognitive strategies in the context of the subject matter being taught results in improved learning and understanding in subjects including physics, written composition, and mathematical problem solving. Moreover, the use of metacognitive strategies has been shown to "increase the degree to which students transfer knowledge to new settings and events" (p. 15), the foundation of proficiency. In today's ever-changing high tech world, those who are capable of learning new things and adapting to change will be much better positioned to excel as productive members of the 21st century workforce.

Metacognition has been described as an "internal dialog" with oneself regarding knowledge about a particular subject to be learned or task at hand, the strategies and resources needed to accomplish the learning objective or task, and the process of planning, monitoring and evaluating progress in route to accomplishing the learning objective or completing the task at hand. Central to developing the metacognitive ability is the process is reflection. As suggested earlier, providing students the opportunity to engage in active learning by allowing class time to pause and reflect on their understanding of course material, whether alone or as part of a group, can also improve metacognitive ability. Another simple strategy that can be used to improve metacognitive ability is by goal setting[36]. Schunk[42] contends that requiring students to set specific short-term (proximal) and long-term (distal) learning goals is critical in developing self-regulation skills because it helps learners focus on the task at hand, identify and apply appropriate strategies, and monitor goal progress. By subdividing overall course goals into smaller "manageable" learning goals with specific and measurable learning objectives, and requiring that students develop a plan for reaching those objectives that includes identifying knowledge gaps, resources needed, monitoring strategies, and timelines, students will develop the metacognitive skills needed self-regulate their own learning – the skills necessary for lifelong learning.

Critical to the process of metacognitive development among learners is feedback. Butler and Winne[37] argue that feedback "is inherent in and a prime determiner of the processes that constitute self-regulated learning" (p. 245). Butler and Winne[37] maintain that when learners establish a plan for engaging in a learning activity, they generate specific criteria against which their performance can be monitored. Upon engaging in the learning activity, learners' ability to self-regulate their learning is dependent upon both internal feedback (i.e., monitoring one's own comprehension) as well as external feedback (i.e., feedback from instructors, peers, and others) in order to gage performance and provide corrective action. While metacognitive ability may be inherent in some individuals, it can be developed through the process of *scaffolding*, whereby instructors provide specific cues and feedback designed to help students focus on regulating their own learning[38, 39, 40]. Research has shown that through scaffolding, learners can shift from an "instructor-directed" approach to a "self-regulated" approach their own learning[41]. In sum, by helping learners develop the metacognitive skills needed to plan, monitor, and evaluate their own learning, they will acquire the crucial skills needed to engage in lifelong learning.

Putting it all together

The purpose of this paper was to develop a pedagogical framework, grounded in research, for re-engineering engineering technician education. Through examination of the literature on adult and experiential learning, a theoretical basis was established that supports an interdisciplinary systems-engineering approach to engineering technician education aimed at developing learner proficiency through active learning, real-world problem solving, and metacognitive development. Numerous strategies for improving learner proficiency were presented, all with the intent of improving learning outcomes for engineering technicians faced with the challenge of learning a complex body of knowledge over a relatively short period of time, and more importantly, being able to skillfully apply that knowledge in real world situations. Critical to the development of proficiency is the development of the metacognitive skills needed to engage in lifelong learning. In Table 1, we provide a summary of the specific strategies cited and examples that can be applied in the classroom aimed at enhancing learner proficiency in engineering technician education. While the strategies and examples are presented in a generic sense, they can be modified and adapted to address the specific needs of many interrelated technical disciplines that constitute the field of engineering technology. One suggestion for future work is to apply the strategies presented in this paper in addressing the requirements of ABET EC-2000 in an actual two-year engineering technology curriculum to determine the effect on learning outcomes as compared to traditional lecture-based methods.

Table 1 – Instructional Strategies for Developing Learner Proficiency in Engineering Technician Education

Strategy	Example
1. Apply an interdisciplinary systems-level approach to engineering technician education team-taught using a "top-down" methodology.	– Develop a detailed curriculum map for students that show when and where specific knowledge and skills will be acquired and how topics are linked. – Prior to instruction, interdisciplinary faculty teams present a system level overview of a real-world application (e.g., DC power supply, robot control system, residential wiring) related to topic of discussion. – Emphasize functional blocks, input/output requirements, manufacturability, materials, cross-disciplinary applications, knowledge required in subsequent coursework. – Hold interdisciplinary seminars on how specific products or systems work, how they are manufactured, required engineering documentation, and suggested improvements. – Discuss the potential impact of products or systems on physically challenged users, environment, and society. – Hold interdisciplinary capstone project discussions and planning early on in the curriculum to focus future learning and stimulate ideas. – Organize interdisciplinary student teams to review and critique capstone course products from previous year. – Organize interdisciplinary student teams to complete capstone project culminating in real-world products or improvements to capstone products from previous year.

Table 1 (Continued) – Instructional Strategies for Developing Learner Proficiency in Engineering Technician Education

Strategy	Example
2. Develop clear and measurable learning goals and objectives presented in the context of an engineering system or application.	– Actively involve industry advisory board in developing clear and measurable learning objectives and performance measures based on real world employability standards. – Identify students' prior knowledge and skills gaps prior to instruction elicit and engage preconceptions. – Interdisciplinary student teams review and critique capstone course product or outcomes from previous year. Emphasize identifying and defining educational "holes". – Work with students to develop a curriculum "roadmap" for addressing educational gaps and identify critical skills needed. – Building on prior knowledge, identify specific learning objectives based on real world employability skills and develop a clear pathway for developing and demonstrating proficiency in those skills. – Develop individual learning contracts with a detailed performance rubric. – Challenge students to link new knowledge to prior knowledge and/or find new applications for their knowledge & skills.
3. Provide frequent and ongoing performance feedback to help students gage their progress towards achievement of specific learning goals.	– Provide students with frequent and ongoing performance feedback (formative assessment) based on clearly defined learning goals and objectives. – Use multiple measures (e.g., group problem solving, self-tests, demonstration of lab skills) designed to improve performance on specific tasks. – Provide students with ample opportunities to hone their skills through a variety of different applications and experiences. – Assign multiple homework problems with increasing complexity and allow class time for group problem solving to provide peer feedback, – Encourage peer review/grading of coursework, and peer teaching/demonstration of skills. – Challenge students to link new knowledge to prior knowledge and/or find new applications for their knowledge & skills.
4. Provide learners concrete experience with new concepts or application *before* engaging in an in-depth theoretical analysis.	– Prior to a classroom discussion on a particular topic, provide students with a demonstration or experiment in which they document their observations and try to connect their observations to prior experience or through the use of analogies. – Engage students in group discussions focused on answering specific questions regarding their observations before engaging in a theoretical analysis. Repeat this process for each new topic.

Table 1 (Continued) – Instructional Strategies for Developing Learner Proficiency in Engineering Technician Education

Strategy	Example
5. Facilitate collaborative learning through interdisciplinary teamwork and group reflection activities.	– Using a problem-based learning approach, organize interdisciplinary student teams to collaborate on the design or redesign of a product or system using lessons learned. – Organize interdisciplinary "brainstorming" sessions with industry participation to encourage teamwork and enhance motivation. – Require students clearly identify team member responsibilities and performance criteria for peer performance review. – Provide adequate class time for group reflection activities. – Require project teams conduct periodic design reviews to evaluate progress and determine corrective action.
6. Use active learning strategies in the classroom	– Provide students with a balance of learning experiences; learning that involves hands-on experience, problem solving exercises, reflection, formulating generalizations, applying knowledge to new situations, and feedback that actively engages students in constructing, organizing, and experimenting with a rich knowledge base. – Provide student teams with "bugged" product concepts. Teams are to analyze a series of flawed systems (e.g., a faulty power supply, motor control system, or audio amplifier) and redesign by applying course content knowledge. – Have students search the Internet for standard components that may be purchased, test out their new design, and make a presentation to the class on their problem solving methods and solution. – Have student teams design, manufacture and test design prototypes using different manufacturing methods (e.g. rapid prototyping vs. traditional machining) and report out on the impact to the two methods in the design. Emphasize cost, time to market, accuracy, form, fit, and function.
7. Scaffold the development of students' metacognitive skills	– Require students set specific short term learning goals. – Provide instructional cues, timely feedback to help students develop self-regulation skills. – Allocate classroom time for individual and group reflection. – Require students to maintain reflective journals to document their learning progress. – Provide ample resources and opportunities to assist students in planning, monitoring and evaluate their own learning (e.g., detailed course outlines and timelines, self-tests and quizzes, constructive and timely feedback)

Table 1 (Continued) – Instructional Strategies for Developing Learner Proficiency in Engineering Technician Education

Strategy	Example
8. Involve industry in the development of curriculum content, learning objectives, real-world problems, and assessment criteria for learning outcomes.	– Organize field trips, guest lecturers, and internships with business/industry to provide students with concrete experiences. – Include student representatives in semi-annual industrial advisory board meetings. – Solicit industry sponsorship for capstone design projects starting at the beginning of the curriculum rather than in the last semester. – Encourage industry mentors to “adopt” students early on and support them in developing concepts for their capstone projects. – Use industry standards to assess and evaluate learning outcomes – Participate in faculty summer industry internships to maintain curriculum relevancy

Conclusion

In this paper we presented specific strategies, grounded in research research, for developing learner proficiency in engineering technician education; individuals who have a well-organized knowledge base and skills set that they can apply to solve specific problems of practice, and who are ready to learn and adapt as technology changes. As mandated by ABET EC-2000, graduates of two- and four-year engineering technology programs must demonstrate proficiency in mathematics, science, and engineering, be able to work in multidisciplinary teams, communicate effectively, be sensitive to the social and ethical issues related to the engineering technology profession, and develop the capacity for lifelong learning. Given the time limitation of two-year technician education, specific strategies for restructuring two-year engineering technology curricula using an interdisciplinary systems engineering approach based on active learning, real-world problem solving, and metacognitive development with the goal of developing and learner proficiency in engineering technician education was presented.

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