AC 2011-1078: GATEWAY EXPERIENCES TO ENGINEERING TECHNOLOGY: DEVELOPMENT OF AN INTRODUCTORY COURSE

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Gateway Experiences to Engineering Technology: Development of an Introductory Course
ETD IT/IET Interest Group

Abstract

The launch of a new Engineering Technology undergraduate degree at Purdue University prompted intracollege collaboration from six different disciplines within the College of Technology. With a flexible curriculum designed to meet existing and future workforce needs, the program of study incorporated both new and revised courses. One of the new courses is a 'gateway' Introduction to Engineering Technology course designed to attract and retain both traditional and non-traditional students. In this introductory course, Engineering Technology (ET) is defined based on the description of the skill set needed for the current and future economy. Through a case study approach, the blended curriculum is delivered as a holistic, integrated approach to technology systems.

The course employs a reverse course-content-delivery design whereby students engage the traditional lecture-based subject matter in a manner that is user friendly and encourages students to revisit lectures as their needs demand. Students work through a specific series of at-home assignments in a chronologically linear manner, labeled simply as 'read', 'watch', 'do'. These assignments build upon each other to develop both depth and breadth through repeated exposure and analysis of core concepts related to the assigned module. For example, students are be assigned to read a chapter on Principles of Engineering Computations followed by a 45-minute recorded video lecture on Engineering Computations. The lecture, based upon Advanced Technology Education foundations, will build upon the reading and help distill the reading material into a more palatable and understandable context. Finally, students will complete the first half of a homework assignment that will be used the next class session for discussion and a hands-on activity. This sequence exposes students to subject matter in an iterative approach to repeatedly allow students the opportunity to experience expectation failure.

The learning theory literature is replete with studies showing that when students experience expectation failure, followed by a time of thorough and investigative feedback loops, learning gains are increased almost fourfold, from 20-30% to nearly 80%[1]. In addition, based upon student persistence theory[24], common student experiences are developed for both ET content and the social learning aspect of higher education to create learning-communities for the gateway students[2]. Problems of a technical, operational, and social nature are introduced and investigated within the course. Connections to the different academic disciplines comprising ET, from multiple departmental instructors, are included and incorporated into the case study.

Introduction

Technology education must mirror workforce needs and the needs today are rapidly changing. Many students of technology systems are being educated to work with systems and technologies that may not yet exist for 5-10 years. Since it is difficult to understand, to predict, and to forecast workforce needs, educators might mitigate this lack of understanding by thinking dichotomously about the short term and long term results of student learning. Short term goals and objectives typically revolve around the knowledge and skills of particular cognate areas. Long-term goals may include providing students the understanding that learning is a continual process and that graduates merely be embarking on a long journey. In the area of teaching technology, this gap between what is learned today and the residual of such knowledge on the long-term impact of education is wider than other fields. Technology educators understand that there is a ‘half-life’ of the particular and immediate subject areas of technology. The nature of teaching technology is to be conscious of the changes around us. Technology educators understand that to be on the leading edge of technology-change is an exercise of continual evaluation and learning. Educators must evaluate technology before adoption to determine if the technology change will result in improvement to a student’s academic experience. The rapidness of change seems daunting since the purposeful and recreational purposes of technology are blending. A university is a micro-world of learning; an academic imitation of what people should know and understand to prepare them for a global economy, where the impact of technology has resulted in authentic evolution of jobs through the process of creative destruction. We will describe advanced technology education; advanced because forward thinking and preemptive development are characteristics of efforts needed to forecast what students will need in the next 5 years. Integration may be another identified concept since authentic problems come in whole[3].

As we consider national needs, there is an emphasis for advanced technology education as a predominant strategy to compete globally[4]. Federal needs revolve around filling workforce requirements across the spectrum of the economy. For this reading audience, this idea means producing not only more engineers but engineering technologists as well. The idea has merit since innovation is another characteristic of the new economy and this involves the theoretical and applied[5]. In this paper, for the purpose of creating a model that exhibits reproducibility and repeatability, specifics will be discussed. Explicitly, educators will emphasize regional requirements. With an emphasis on engineering technology, reflection of the current state of performance and regional goals, in this case Indiana, illustrates why an evolving academic curriculum is in order.

To compete in a global environment, as part of a large economic region, Indiana falls short. A key to continued competitiveness is a workforce educated and trained for the 21st century. Currently, for an adult population holding a bachelor’s degree, the Hoosier state ranks 41st among all states (tied with TN)[6]. Furthermore, the aging demographic threatens Indiana’s position as a business friendly environment and may open a gap between the skills a workforce possesses and what is required, much less desired[7]. The potential problem is best exhibited by what is represented economically in the state. Indiana still has considerable manufacturing representation with manufacturing in the state constituting 17 percent of the total private sector employment[8]. Moreover, the business climate report states that the

Indiana workforce is weak and lacks a global mindset, believes to be entitled, and lacks sophistication[9]. Manufacturing represents a broad spectrum of skills, and an area of study that captures a similarly wide-range of workforce needs is engineering technology (ET).

Engineering Technology is recognized as a field that is primarily focused on engineering ideas, values, and the technical skills for development through application[10]. ET is broadly defined by areas of research, production, operations, and programs that are designed for specific engineering-related fields[11]. As a broad discipline, engineering technology incorporates cognate areas that often cross academic departmental boundaries to meet the goal of integrating the areas involved under one degree program. Engineering technology is an area that emphasizes the teaching of industry-standard technical information and skills, preparing graduates for immediate productivity to society, integrating general and technical skills and knowledge, and responding to changing market demands[12]. These principles are well defined and constant, and serve to guide educators in evaluating and revising engineering technology programs as society demands.

Development

There has been much written on the engineering technology discipline and a reflection could be provided to give a historical perspective of where engineering technology is today for perspective. To succinctly state what engineering technology could represent for educational development purposes, the perspective of linking K-12 into a K-16 mindset could help educators understand a pathway approach to engineering technology. This pathway may help higher education understand that the economy requires individuals educated across a broad spectrum of job opportunities. Barbieri, Attarzadeh, Pascali, Shireen, and Fitzgibbon[13] describe an educational model whereby students self select based upon personal preferences, in this case either engineering or technology fields. From a national perspective, an engineering technology degree should reflect what society desires, and society today requires personnel in not only engineering and technology areas, but with a full integration of Science, Technology, Education, and Mathematics (STEM) potential.

The concept of integration can be borrowed from teaching technology with regard to preparing students for STEM careers and used for development of an engineering technology discipline. The need for STEM education encompasses educational efforts from primary through higher education levels[14]. Interconnecting STEM areas requires blurring of the academic boundaries present to fulfill these needs[14,15]. To guide development of an ET degree, principles of integration should be defined with the same diligence. Practice in industry is based on using many different technical skills, regardless of where the skills are gained. Industry takes graduates and integrates them into their company's systems, working on their issues, almost regardless of the academic discipline they studied. In higher education, this is defined as an interdisciplinary process. It is necessary to understand what this term means for guiding the development of a degree program based upon this premise. Interdisciplinary understanding has been defined as the capacity to integrate knowledge from more than one discipline for cognitive purposes[14]. According to Kelly[14] the advantage of interdisciplinary learning is to create understanding that will have been unlikely through a single discipline. The blurring of disciplinary boundaries, as stated by Burghhardt and

Hacker[16] and Kelly[14] advocates for development of integrated STEM curriculum and is a premise that guides educators in developing an engineering technology degree.

Purdue Engineering Technology

The field of engineering technology has been well documented as an explicit academic discipline[17]. For Purdue University, an Engineering Technology degree is a recent offering. The degree has been created based, in part, upon inquiry and discussion with multiple stakeholders such as industry, alumni, legislative representatives, and others.

The ET degree program at Purdue is geared toward application of ideas and theories and innovation. It is based on the foundation of STEM fields and draws from cognate areas, represented by academic departments including a broad range of experiences in: Electrical and Computing Engineering Technology, Computer Graphics Technology, Computer and Information Technology, Industrial Technology, Mechanical Engineering Technology, and Organizational Leadership and Supervision[11]. The ET plan of study is shown in the table below:

	Semester 1	**Cr**		**Semester 2**	**Cr**
COM 11400	Fund'ls of Speech Com	3	MA 22100	Calculus for Technology I	3
MA 15900	Pre-calculus	5	Elective	Freshman Composition	3
TECH 10500	Intro to Eng Technology	3	MET 11100	Applied Statics	3
MET 14300 or MET 14400	Materials & Processes I/ Materials & Processes II	3	C&IT 15500	Introduction to Object-Oriented Programming	3
CGT 11000 or CGT 11600	Technical Graphics/Geometric Modeling for Vis & Com	3	OLS 25200	Human Relations in Organizations	3
	Semester 3	**Cr**		**Semester 4**	**Cr**
C&IT 27600	Systems Software and Networking	3	ECON 21000	Principles of Economics	3
PHYS 21800	General Physics	4		ECET Core Selective	3
MET 24500	Manufacturing Systems	3	IT 21400	Intro to Lean Mfg	3
CGT 22600	Introduction to Constraint-Based Modeling	3		Technical Selective *****	3
	General Hum/SS/LA	3		Lab Science Selective	4
	Semester 5	**Cr**		**Semester 6**	**Cr**
COM 32000	Small Group Communication	3	ENG 42100	Technical Writing	3
IT 34200	Intro to Statistical Quality	3	IT 44600	Six Sigma Quality	3
ECET	ECET Core Selective	3	OLS 28400	Leadership Principles	3
	Technical Selective *****	3		Technical Selective *****	3
	Gen Hum/SS/LA	3		Free Elective	3
	Semester 7			**Semester 8**	

IET 45100 or IT 45000	Production Cost Analysis or Monetary Analysis	3	TECH 49700	Senior Design Project	2
OLS 45000	Project Management	3		Technical Selective *****	3
	Technical Selective *****	3		Technical Selective *****	3
COM 30300 or COM 31400	Intercultural Communication or Adv Presentational Speaking	3	Selective	Global, Cultural, or Diversity	3
	Free Elective	3		Free Elective	3
TECH 49600	Senior Design Project Proposal	1			
*Technical Selectives are intended for Concentration					

Table 1: Engineering Technology Plan of Study

The ET plan of study fulfills the overall program objectives. The degree program serves both student and industry clients by employing technical knowledge, problem-solving techniques, and applied engineering and technology skills in traditional and emerging areas[18]. ET graduates will be prepared to actively participate in ongoing professional development for professional career growth. The foundation of these characteristics serves an advancing career path that is evidenced through gradually increasing professional responsibility, or job scope. Not only does the program design serve the individual's motivation to advance, but is also responsive to emerging technologies and technical systems [18].

To extend degree usefulness beyond technical proficiency, students will be able to document and present technical information in written and oral form to technical and non-technical personnel[19]. The importance for good communication skills are consistently being publicized as a workforce requirement for college graduates, especially for those in highly technical areas of study[19]. It is no longer sufficient to simply master cognate areas, but must be tempered with the ability to effectively communicate about technology and systems to even non-technical constituents. As a program objective, ET graduates will have the ability to work effectively and recognize that industry trends incorporate project management, collaboration, and use more recent operations innovations (such as lean manufacturing) combined with traditional engineering principles[20]. In order to complete the program objectives, the curriculum is broken down in the following areas:

- General Education Courses – 46 credit hours
- Required Technical Core Courses – 51 credit hours
- Technology Selective Courses – 18 credit hours
- Electives – 9 credit hours

In summary, the flexibility of the ET degree meets the statewide needs of the Indiana workforce and community. Engineering technology as a discipline will provide graduates with a solid foundation in engineering principles, giving flexibility for degree students, and meeting particular industry and regional needs. Finally, the flexibility of the ET degree also lends itself to remote delivery. The ET degree is delivered across multiple Purdue locations to reach students that are embedded in their community. With a statewide mission, there is an opportunity to reach students who might not go through a more traditional path. The challenge of limited resources while providing a consistent level of delivery is also present. The flexibility of the ET degree allows variability in the administration of the program, while recognizing the challenge of employing local resources to deliver the content of the ET program.

Gateway Experience to Engineering Technology

Degree flexibility is a challenge to providing a consistent student experience. The ET degree is based on the idea of integrating concepts, principles, and techniques from multiple academic departments. The academic units involved have differing program objectives and serve a variety of students. Integration of the ET degree requires extensive faculty collaboration to provide a common student experience. The concept of a 'gateway' experience is one way to introduce students to a degree program, and provide a means for faculty to collaborate across their particular units. An introduction to engineering technology course (TECH 105) has been created to provide a gateway and common student experience as the basis for the rest of the degree program. While it is generally accepted that all freshman students do not have identical backgrounds, experiences, nor similar levels of academic achievement, this thus serves to establish a baseline set of competencies that will be built upon in later courses.

The TECH 105 course introduces students to the different disciplines that comprise engineering technology at Purdue University. The course content includes systems engineering, quality improvement, and management of processes and projects. The overall skill sets needed by a technology knowledge worker are introduced. These skills include problem solving, communication, teamwork, and professional development. A goal of the course is to provide focus, including a holistic approach to technology systems[21].

In addition to introducing the diverse disciplines to students in a seamlessly threaded package, the TECH 105 course provides a common experience that promotes more student involvement in the classroom via collaborative learning through shared knowledge and shared knowing[22,23]. Students construct and discover shared knowledge for an enhanced cooperative learning experience; which is enhanced by including linked activities tied to the curriculum for a coherent, related experience[24]. Shared knowing is based upon students sharing a particular transition point, such as becoming freshman, or an initial educational experience[25]. The TECH 105 class provides a transition point for students by introducing learners to a pseudo-cohort classroom experience at the beginning of the ET curriculum, including through the use of active learning.

TECH 105 students actively participate through a social learning model, to explore issues and ideas with guidance from the instructor[26]. Student learning is the key point and active learning experiences, shared with peers engaged academically and socially in a learning environment, are important characteristics of the TECH 105 course[27]. The students learn an approach of asking questions, searching for answers, and interpreting observations. The method of designing content by modules, rather than content introduced as separate academic disciplines, is done to aid the students in interpreting and evaluating engineering technology as a whole, and to seamlessly integrate the different departmental content. For application activities, problems of a technical, operational, and human nature are introduced and investigated as part of in-class work. A case study of an emerging, advanced manufacturing or supply chain system is used to demonstrate the disciplines of engineering technology. By designing the course to equate and minimize the differences of the various academic units, the expectation is for students to create connections regardless of the faculty member who created the TECH 105 course content module. With a very specific and rigorous content and modular-design philosophy intact, delivery is accomplished by creating multiple approaches to allow for different ET locations to coordinate classes in a traditional, distance, or hybrid manner.

Modular Approach

For this gateway course, the content is created through modules intended to meet the course objectives while tying the diverse course content together. The modules provided the core content in the form of a self-contained, platform-agnostic audio/video presentation; the core modules are listed below in Table 2.

Students will be introduced to various aspects of computer modeling, including solid/surface modeling.
Students will be introduced to various aspects of computer simulations, including animation, and multimedia/web applications.
Students will be introduced to multi-tier applications including user and machine interface, application software, and database components.
Students will be introduced to the infrastructure of computer networks.
To provide students with an introduction to the technology and provide them with a working knowledge of basic electrical quantities (voltage, current, resistance, and power)
Understand the difference between AC and DC, their units (volt, amp, Ohm, Watt), their “role” in electrical technology, and safety as it pertains to working with electrical systems
Student will understand disciplined problem solving tools and apply them for continuous improvement.
Demonstrate understanding and application of basic organizational and management concepts
Apply the general solution format known as GFSA, Given-Find-Solution-Answer.
Apply both U.S. Customary and S.I. (metric) units, and the factor-label method of converting units.
The student will learn how to form and work in teams and work in collaboration.
The student will understand how to lead multifaceted groups.
Students will understand and apply university library resources.

Table 2. Introduction to Engineering Technology Course Objectives

The specific design for these modules included criteria for ‘timeless’ and/or plug-and-play design characteristics. The modules are recorded without reference to time, department, or other external information that identified a particular module beyond the core content of the information delivered therein. The purpose is that the deliverable be timeless, not implying that the information or systems for this material is unchanging, rather that it is able to be offered at different times without student discord, and is more keyed to consistent patterns of thinking, doing and interacting.

Working to develop content that can be reused easily, yet is not so generic as to be useless, is a challenge for some content, such as the library module in the course. Ideally, library content is directly tied to a task the students are currently working on in a class, thus leveraging the ability to apply the new knowledge in a specific context and assist the retention of new information or processes. For a willing collaborator, but one not involved in all of the course development and discussions, it has been a challenge to develop the module so it will have the most benefit to the students and the work being done for the overall course project.

To overcome the limitations of having such stringent design requirements for the audio/video (A/V) modules, the lesson plan model is based upon the idea of a two-part approach. As homework, the students will read, watch, and then do; the second part of the approach involved the students participating in an in-depth in-class discussion of the homework material during the next class session. The discussions had to be directly tied to the A/V material so as to provide the otherwise missing components that will aid in the dissection and digestion of the modular content.

The video modules are made available for students to watch during the week before that particular lesson was to be discussed in class. Students are also expected to read assigned material that applied to the particular module. During the face-to-face class, the session focused on discussion and dialogue, correcting issues students encountered, and providing specific application and relevancy of the content. Therefore, the at-home a/v modules allowed for faculty to spend in-class time on creating the needed relevance to increase learning gains rather than spending the lecture time merely introducing the material. The lessons are designed using active learning techniques to enable the students and the instructor to engage the material in a reflective manner. Developers are asked to provide 30-45 minutes of discussion material that directly related to the module in the form of a lesson plan. This could include new material to be covered by the instructor, but most importantly included a short classroom activity (ideally hands-on) to allow the instructor time to help students digest materials covered in the readings, A/V modules, and homework assignments.

There has been much discourse among faculty on how to integrate the differing material into one cohesive and integrated course. The result has been to create a semester long project that integrated the course material, and involved field trips, case studies, and practical, applied content. The problem and/or case study activity selected is related to wind power generation and distribution. The case is not presented in the A/V modules in order to preserve their reusable or 'timeless' characteristic, and is instead directly incorporated into the classroom sessions. Designed in this manner, the case study can be changed as time and technology progression allows, reserving the core lecture content as unchanged in the a/v modules, and thus employing the faculty as the integrator of content from pure theory to real-world application. The case study helped thread the different material together by integrating modules through student engagement. A faculty goal is to have a case study produce artifacts that demonstrated student competency of the material, and additionally produce something the students collaboratively built as a cohort. By semester's end, an internet wiki will be created by students, applying the ET material to meet the case study objectives. Student collaboration is a critical design feature of the TECH 105 course incorporated into the curriculum.

A final feature worth mentioning is the aspect of social learning; social interaction, particularly dialogue, is an aspect that has received little attention but warrants conversation.

A fundamental feature of the gateway course has been the utilization of a learning community aspect to foster knowledge in a dynamic social setting. Many of the students obtaining a statewide degree commute to and from, as opposed to residing on, campus. As a result, interaction outside of the classroom can often be limited. With the inception of the Engineering Technology program, the intent is to create a holistic learning experience that compensated for student living arrangements and enabled relationship-creation at the foundational level of the program. The result is the incorporation of a learning community concept as a component of the 'gateway' course's flexible curriculum design at both the course and statewide level. This element is included to help foster social interaction and nurture academic growth through collaborative activities.

While academic success may be achieved on an individual basis, often the by-products of group alliances yield more insightful and intellectually grounded outputs for students, ultimately resulting in increased learning gains[28]. Establishing a sense of community in the gateway class is accomplished through the implementation of multiple activities. For example, collaborative interactions are initiated through the students posting their own personal profile on a global wiki. This enabled high-quality peer-to-peer communication both in individual courses and in courses offered across the state. Each class conducted a literature review, with each student posting their citations, analysis, and discussion of the literature to the wiki. These wiki-based literature reviews are then accessible to all students enrolled in TECH 105 throughout the state. Most importantly, the online dialogue is the first step in students beginning to view one another as colleagues, or even friends. It is common knowledge that interaction amongst friends varies greatly from interaction between acquaintances. The course design took into account the premise that if friendships are established early on, the students will be socially fulfilled and student persistence and probable advancements in engineering, science, technology, and math will occur at significant points in the student's college career. It is believed that learning communities will assist in the accomplishment of that goal. Stimulating learning in a community setting will ultimately result in student persistence and learning.

In the learning community modules, students are given the opportunity to explore the effects of cooperation and competition among group members to solve a group problem presented in the form of a puzzle. Members are intentionally chosen to demonstrate cooperative or conflicting behavior. The objective is to raise student awareness regarding how cooperative behavior is more conducive to achieving results in a group setting. In addition to activities that foster social interaction, intellectual activities are also chosen. Students in a social learning context put more effort into that form of educational activity that enables them to bridge the academic-social divide so that they are able to make friends and learn at the same time[24].

A second learning community activity is an all-classes field trip. Early in the semester, students from all sections (all statewide locations) attended an on-site industrial tour of a manufacturing plant. As a sub-goal of the trip, students are matched with a peer from another location and provided an opportunity to socialize while cooperatively completing a 'Site Inspection checklist' during a plant tour. The trip brought many of the Purdue ET community together, if only for a short time. The tour gave students the opportunity to interact with peers, business personnel supporting the degree program, and see principles of Engineering Technology applied to industry. However, these interactions are reinforced and continued through the use of the class wiki.

The final learning community activity focused on being able to identify the factors of effective communication during problem solving, especially those related to graphical visualization of engineering data. Striving to understand the message with clarity and void of interruptions can mitigate the chance for miscommunication. When communicating in a group setting, the possibility exists that not all group members receive and interpret messages the same way, resulting in ineffective communication. Students learned that active listening and reflection during the decoding phase of communication are key components to this skill set and when done with intention leads to a clear sense of understanding. There is statistical evidence that students who are involved with the people and activities of learning communities are significantly more likely than their less involved peers to show growth in intellectual interested and values, and subsequently are more likely to get more out of their college education[24]. The progress, retention, and success of this cohort will be monitored as they progress through the Engineering Technology program to measure if the camaraderie fostered through the gateway course made a substantial impact.

Results and Conclusions

The TECH 105 is delivered across multiple ET locations. A future outcome of this work that might be of interest to the academic community would be to understand how to create a reproducible process of course creation for ET. A variety of activities are thoughtfully implemented in order to accomplish the multiple objectives of the ET degree program. Coordination among faculty is a challenge requiring conversations leading to trust, for the purpose of science. Werner Heisenberg (formulator of the famous "Uncertainty Principle" in modern physics) argues that the field of science is rooted in conversations and the cooperation of differing personnel might culminate in results of paramount importance[3]. With the roots of the Engineering Technology program founded in science, technology, engineering, and mathematics, the cooperative learning model has been identified as the ideal framework, lending itself to academic achievement through group interaction. In order for the work to occur, dialogue among faculty is required to meet the personal need to feel comfortable and at ease. Prior to the commencement of the course design phase, free flowing conversations and dialogue, peer introduction, familiarization and acceptance must occur. During the design phase, social and intellectual interaction for the purpose of learning is identified as a fundamental component of the program. It turns out that the interaction is the primary artifact of the design process among faculty as well. If the only thing that is sustainable in an organization is the interaction among faculty, this may hold true as a result of this process as well.

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