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Developing Interprofessional Skills in a Clinical Engineering Program*

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Clinical Engineering and Biomedical Engineering Technology academic programs should follow the current demands of their industry to become updated and competitive in order to train highly qualified professionals. Today, the role of clinical engineers is shifting from merely repairing and maintaining medical equipment to becoming the managers of the instrumental resources in their healthcare institution. This new approach to Clinical Engineering creates the need for technicians to possess a wide range of interprofessional skills. The Wilkes-Barre Campus of the Penn State University has been training Biomedical Engineering Technology professionals since 1967, constantly updating its program to ensure the quality of the graduates. This paper describes the different academic activities and approaches developed by the author since his incorporation into the program in 1996.

INTRODUCTION

THE AIM of this paper is to describe the approach taken by the author in developing a new approach to the Biomedical Engineering Technology (BET) program at the Wilkes-Barre campus of the Penn State University. This is an Associate of Applied Science degree in Engineering Technology (2-year degree), accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC of ABET). Table 1 shows the course work that the students need to complete in order to graduate. It can be seen how the students take the courses aimed specifically towards Biomedical Engineering Technology in their sophomore year. The goal of the BET program is to train students in the arts of maintaining, repairing and managing medical and clinical equipment, making them highly qualified professionals for the service of their institutions and the society. These goals are somewhat different from the most known biomedical engineering programs where the students aim to pursue careers in the research and development of medical instrumentation, and consequently the academic activities to ensure the completion of these goals are different. Sometimes the technical and academic literature distinguishes between Biomedical Engineering Technology and Clinical Engineering, based normally on the requirements for certification by the Association for the Advancement of Medical Instrumentation (AAMI). However, to avoid unnecessary confusion, this paper will use both terms indistinctly, as all the activities described here can be incorporated in either program.

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As the clinical community is increasingly dependent on technology for preventive medicine, diagnosis, therapeutic care and rehabilitation, clinical engineers play an increasingly important role in their healthcare organizations. Their responsibilities have evolved from being basically involved in carrying out preventive maintenance and repairing damaged equipment in the past, to becoming technology managers by educating and training clinical staff on the technical aspects of medical instrumentation [1]. Clinical engineers provide extensive engineering services for the clinical staff, being increasingly accepted as valuable team members by physicians, nurses and other healthcare personnel. Some of their typical responsibilities include [2]:

- the prepurchase evaluation of equipment and the planning for new equipment;
- the design, modification or repair of medical instruments or systems; the calibration procedures for clinical equipment;
- the inspection of incoming equipment either new or after repairs;
- the inventory control of equipment inside the hospital and its localization;
- the training of medical personnel in the safe and effective use of medical systems;
- the input into the design of clinical facilities where technology is heavily used;
- the development and implementation of documentation protocols required by external accreditation and licensing agencies, among others.

In this continuously evolving scenario, it is necessary to prepare future professionals for the current demands of industry as well as its future needs. Education in Clinical Engineering and Biomedical Engineering Technology has to address both these

Table 1. Coursework required for graduation in the BET Program at Penn State, Wilkes-Barre. The specific courses in BET (indicated in bold) are taken in the sophomore year.

BET graduation requirements	
1st semester	**2nd semester**
Electrical Circuits I (3)	Electrical Circuits II (4)
Electrical Circuits Laboratory I (1)	Electrical Circuits Laboratory II (1)
Engineering Orientation (1)	Digital Electronics (3)
Technical Math I (3)	Digital Electronics Laboratory (1)
Technical Drawing Fundamentals (1)	Experimental Methods (1)
Introduction to CAD (1)	Technical Math II (3)
Rhetoric & Composition (3)	Technical Physics (3)
Social/Arts/Humanities Elective I (3)	Social/Arts/Humanities Elective II (3)
3rd semester	**4th semester**
Biomedical Transducers (5)	Physiology (3)
Social/Arts/Humanities Elective III (3)	Biomedical Instrumentation & Systems (5)
Technical Elective (3)	Medical & Clinical Equipment (3)
Technical Calculus (4)	Introduction to Chemistry (3)
Fundamentals of Semiconductors (2)	Effective Speech (3)
Semiconductors Laboratory (1)	
5th semester (summer)	
Clinical Internship (4)	

new challenges and the dynamics of a strongly competitive and global market, while providing the same basic knowledge of medical equipment as it has been successfully done in the past. Employers not only demand high technical skills from prospective employees, but also work experience, team work and especially outstanding communication skills as they are proven to be critical in the work environment [3]. This paper will explore and discuss the different academic objectives developed to ensure that the goal is satisfied, and will also assess the impact of each one of the approaches in developing skilled professionals.

ACADEMIC ACTIVITIES

In order to achieve the main goal, a series of objectives in the academic environment have been identified. By developing academic activities that focus on specific points, we expect their achievements to work synergistically in developing the full intellectual and professional potential of the students. These activities complement the traditional lectures and laboratory experiences that provide the building blocks in the students' development into qualified professionals.

Contact with industry

The academic responsibility of BET programs normally resides with instructors who combine their knowledge and industrial experience in order to create lectures and the strong hands-on laboratory experiences that are needed in Engineering Technology programs. Although most of the academic instructors are highly qualified and experienced, it is very difficult, if not impossible, to provide the depth and detail required for each area as well as the breadth of perspective and discussion of current issues that is desirable. It is important for the students to be exposed to a variety of opinions and points of view from different individuals to enhance their critical thinking [4]. This becomes even more effective if they learn from the different industries in their field. Although the job opportunities in the clinical engineering field are continuously increasing, it is possible to identify three main categories of employment [5]. These are:

- The clinical engineering department of a hospital or healthcare organization, where the graduates are responsible for the maintenance and repair of the medical equipment that is not under service contract from its manufacturer. Moreover, in most cases where there is a contract service, they act as the first in-house response to a problem. In addition to this task, they are also responsible for the management of equipment, technical training for clinical staff and the safety of the hospital among others.
- A manufacturer of medical equipment where they provide technical service and support the equipment under service contract. Normally, these technicians specialize in a line of products and are assigned a series of hospitals within a geographical area for which they are responsible.
- An independent service organization that offers its services to a hospital, to be responsible in some cases for general equipment or in other cases only for specialized units, for example, imaging, clinical laboratory, etc. This kind of employment has increased in recent years and it can be expected to continue expanding in the future.

The Guest Lecture Program is a series of highly interactive videoconference lectures used to expose students to the industry. In this program that runs two hours a week during one semester,

professionals from the clinical engineering industry present specific issues in their fields of expertise. Because the BET program involves two campuses of Penn State that are 300 miles apart, the speakers go to one of the campuses and their lectures are transmitted to the other campus by interactive videoconferencing (PicTel^{TM}). This program gives the students at both campuses, whose number ranges from 3 to 9 at each location, the opportunity to learn about the different types of industries in clinical engineering, as well as to learn about the different job roles and their responsibilities. The lectures in the program are balanced between those with high technical content and those that provide a breadth of perspective, as shown in Table 2. The goal of the technical lectures is to teach students, in detail, the technical and functional aspects of different pieces of medical equipment whose basic principles have been already discussed in the classroom. They are also designed to make the students familiar with the configuration of the equipment for normal working condition as an incorrect setup causes a large number of service calls [6]. The breadth of perspective lectures focus on other aspects in the clinical engineering profession that, although traditionally forgotten in academia, will have a strong impact on the professional future of the students. This is especially important as the success of the students as future professionals depends not only on their technical skills, but also on other social and interpersonal skills, mental characteristics, as well as their attitudes and values [7]. The use of videoconferencing allows a speaker to reach the audience of multiple campuses, having to travel to only one of them. Moreover, as more industries use this communication tool, the speakers will be able in the future to reach the students from their companies thus eliminating the cost and inconvenience associated with travel. However, the use of videoconferencing is not exempt from drawbacks. Its major problems are: the degradation in the quality of the image due to image compression needed to reduce the bandwidth and the cost of the transmission that is especially noticeable during fast movements; the audio delay between both ends that, although very small, is strongly perceived at the remote end; and the almost unavoidable losses of communication between both ends that is especially harmful when the speakers are engaged in lecturing rather than interacting with their audience. We need then a period of adaptation for the students to feel comfortable being at the other end of the video link, which normally happens after only a few sessions.

The World-Wide-Web (WWW) is an additional tool for the students to have closer contact with industry. A large number of manufacturers, vendors and distributors of medical equipment have information about their products on the WWW. The students use the WWW as an additional reference source to analyze the market characteristics and trends of different pieces of medical equipment. The use of the WWW has advantages over the media traditionally available, technical literature and brochures from the manufacturers. This literature is costly to produce and distribute which limits their distribution and ability to be updated frequently. By posting this information on-line, the manufacturers can update their catalog of products they offer quickly and at a minimal cost, making it available to a wider audience. The relatively young technology of the WWW, that will hopefully improve in the near future, is one of the main problems encountered during these activities. For example, URL addresses in the WWW are not yet permanent: most of the message errors are cryptic and it is difficult to distinguish when a server is down from when the information has been moved elsewhere. Furthermore, the strong multimedia content in some pages cause the information to be displayed slowly which also increases the frustration and disappointment in the users. The addition of pictures and videoclips brings a new dimension to how technical information is displayed, as the students have the opportunity to view realistic drawings and cuts of the equipment, machines in action, etc. However, this strong multimedia

Table 2. Contents of the Guest Lecture Program, where the students listen to professionals from the different field in clinical engineering

Guest Lecture Program contents	
In-depth technical lectures	Breadth of perspective lectures
Career Trends for Biomedical Engineering Technology	Consequences of Ineffective Technical Writing
Defibrillation Technology	Preparing Effective Resumes
Clinical Practice of Electro-Surgical Units	Interview Tips & Job Prospects
Monitoring of Vital Signs	Independent Service Organizations (ISO) Opportunities
Year 2000 Issues in Healthcare	Writing Business Letters
Introduction to Radiology	Skills for Customer Relations
Introduction to Anesthesia Gas Machines	Osha Regulations: Lockout/Tagout Procedures
Blood Borne Pathogens – Universal Precautions	BMET Relationships with other Health Care Professionals

content increases the required storage space, the time needed to display it and contributes to overloading the WWW. Furthermore, the manufacturers that post information of their products in the WWW do not acknowledge the existence of similar products from their competitors, which makes the students unaware of the market share for each manufacturer. Finally, students may experience problems finding information of relevant interest, as they are not completely familiar with searching strategies and the nonlinear structure of the WWW [8].

Contact with healthcare centers

Field trips to hospitals always have a positive impact on the students as they visualize a real work environment and realize the importance of clinical engineering in the healthcare setting. This is the first contact for the students with a hospital from a different side than being a patient. Students can observe the equipment for which the clinical engineers are responsible, from the most sophisticated and costly new instruments to the simplest and most common equipment. They normally take one field trip per semester, with a duration of approximately 3 hours. In the hospitals, the students have the opportunity to see state-of-the-art equipment in the clinical setting, familiarize themselves with this working environment and understand the role of the clinical engineers in the healthcare institution. The description by the clinical engineering manager of the technician's responsibilities and the equipment that they service can be referenced during lectures, becoming valuable examples in class. The responsibility of the instructor is to put things in perspective, as some students may feel overwhelmed by the amount of equipment needed to operate a hospital. In any case, these field trips to hospitals become a priceless tool to increase the interest of the students in the clinical engineering field. They also serve as the first contact of the students with the clinical engineering department in a hospital where they will do their clinical internship.

The students enrolled in the BET program at Penn State are required to take a 400-hour internship in a hospital before they graduate. In this environment, they have the opportunity to work with large-scale, expensive and critical equipment that is not available in the university laboratories. Students are exposed to all the different services in the hospital, rounding their education in the field. Furthermore, they have the opportunity to work very close with professionals, learning not only technical details, but also the culture of the workplace and how to interact with the clinical staff. The most important benefit from this internship is the experience that the students acquire, making them more attractive to potential employers. During the internship, the students are assigned different supervised tasks, starting from the basic preventive maintenance to taking on more complex and challenging tasks. These activities dramatically increase their self-confidence as they are working without the pressures associated with new employment and realize they are able to carry out these tasks satisfactorily. Their potential for future employment also increases from this internship. As the students have to interact with manufacturers, vendors and technicians from the hospital or independent companies, they become aware of current job openings at these places, expanding their possibilities for a future successful employment. Moreover, as the students have to interact with all of these professionals with different work goals and job responsibilities, they can decide in which particular field within clinical engineering they want to pursue their careers.

Contact with clinical engineering professionals

The interaction of students with clinical engineers is another critical point in their professional and personal development. The last section has described some approaches to exposing students to industry. The contact with industry professionals is particularly intense during the clinical internship, when the students work with other technicians, managers, and clinical personnel, mostly nursing staff. The students are able to observe how the clinical engineers interact with these groups of professionals and learn from their experiences, for example when technicians have to work on a piece of equipment to which a patient is connected. This is a situation that requires not only good technical skills but also strong interpersonal relationships in order to lower the natural anxiety of the patients and their families.

In addition to the personal interaction with the Guest Lecture Program speakers and other technicians and managers during the internship, the students have the opportunity to interact with other professionals by subscribing to technical distribution lists. Students of the BET program are required to subscribe to a distribution list via e-mail, called 'BIOMEDTALK' that carries professional discussion between clinical engineers. This list can be located at listserv@listserv.aol.com. Other available distribution lists with clinical engineering discussions are 'BmElist' (lisproc@nor.com.au) and 'cmbes' (majordomo@clineng.sbrc.umanitoba.ca). Although the students normally do not feel comfortable enough to actively participate in the discussions, they gain a very important experience by reading the messages in the list. They feel part of the professional group, learning their goals, problems and concerns. This feeling of belonging to a professional community cannot be achieved either by classroom lectures or laboratory experiments, making this a unique experience. Some of the most interesting discussions during the regular lectures were brought up by the students based on topics discussed in the distribution list.

Complementing the previous activities, the students have to write critical reviews of articles

Table 3. List of articles from trade and professionals journals given to the students to write critical reviews. These articles are constantly changing, as new contributions appear in the journals. These articles are selected to complement the student exposure to the different areas of clinical engineering.

Title of the article for review	Source
1 Think about it: A patient lay dead in the intensive care unit	*24 x 7 For technical service and support professionals in Healthcare.* July 1998
2 Medical instruments come home. But who keeps then running?	*24 x 7 For technical service and support professionals in Healthcare.* September 1998
3 Is preventive maintenance still a core of clinical engineering?	*Biomedical Instrumentation & Technology*. July 1997
4 Interview: Gail Robinson. Biomed is not longer a man's man world	*24 x 7 For technical service and support professionals in Healthcare.* June 1998
5 Frustrating and flicking: when calling your vendor becomes a pain	*24 x 7 For technical service and support professionals in Healthcare.* January 1998
6 Solving technical challenges in difficult conditions	*Biomedical Instrumentation & Technology*. July 1998
7 Human errors and human factors engineering in health care	*Biomedical Instrumentation & Technology*. November 1997
8 Don't scare the patients !	*24 x 7 For technical service and support professionals in Healthcare.* December 1997
9 The art and science of troubleshooting medical equipment: A model for troubleshooting medical equipment down to the component level	*Biomedical Instrumentation & Technology*. March 1997
9 A survey of the clinical engineer's role within the hospital	*Journal of Clinical Engineering* November 1997
10 Current health care trends and their impact on clinical engineering	*Biomedical Instrumentation & Technology*. May 1997

selected by the instructor from trade and professional journals. The instructor grades the student reviews and provides adequate feedback to ensure that the students are able to understand the key concepts discussed in the article. These articles, that are summarized in Table 3, have been selected to complement their exposure to a broad variety of the topics of interest in clinical engineering, as the majority of the articles discuss issues that are not traditionally addressed in the clinical engineering curriculum.

Learning the culture of the workplace

To succeed in any profession it is indispensable to be aware of what is demanded from professionals in the field and act in consequence according to these expectations. It is necessary not only to have good technical skills, but also to understand the work environment and the culture of the workplace. Students can start learning this culture by doing volunteer work at the Biomedical Engineering shop at different healthcare facilities. They work with senior engineers, assisting them in the most basic troubleshooting and preventive maintenance of medical equipment. Although as faculty we cannot demand that students are involved in these activities, their participation is strongly recommended in the BET program.

The most extensive exposure of students to the culture of the workplace occurs during clinical internship. During this time, in addition to improving their technical skills, students learn how clinical engineers work professionally, learn how they interact with other professionals and in general obtain a good grasp of the field. The students learn about opportunities and possibilities for placement, as they are in contact with other biomedical technicians, technicians working for manufactures, vendors, independent service organizations and contractors. These contacts become professional references for the students thus increasing the possibilities for employment in the area in which they are more interested. Furthermore, during the internship period, the students learn about standard salaries in the different areas of the profession that is very useful once they finish their internship.

Increasing other interdisciplinary skills

The traditional clinical engineering education has focused on giving students knowledge of electronics theory, troubleshooting, maintenance and repair of medical electronic equipment. Although these skills are still needed today, industry demands expertise in additional areas. Clinical engineers need to have knowledge of the clinical operation of the medical equipment, as they may be involved in the decision-making process regarding the purchase of new equipment. They will also be involved in training clinical staff in the technical aspects of the new equipment to reduce the number of service calls caused by an incorrect system operation [9]. During their professional career, clinical engineers often have to write memorandums with technical information, have to interact with a broad range of professionals with very different training and will have to become familiar with the different computer systems that are increasingly used to control equipment, acquire vital signals from patients and locate personnel in the facility. This variety of tasks demands academic activities to develop the professionalism of the future graduates [10].

As medical equipment becomes more reliable, the main responsibility of clinical engineers has moved from almost exclusively repairing equipment to managing the instrumentation resources in the hospital. Modern equipment, although more

reliable, has also a more complex user interface. The expanded and customized possibilities of this equipment is normally displayed through a series of menus and submenus that are accessible by dynamically redefined keys. In this aspect, the clinical staff may have received less extensive training and consequently are more susceptible to making more configuration errors [6]. It is then critical that clinical engineers are able to recognize whether the source of the problem is a malfunction of the equipment that needs further investigation or if it is an erroneous configuration that can be solved instantly. This is especially important in critical equipment such as ventilators, defibrillators and electro-surgical units, for example. To acquire this experience we have developed laboratory coursework in which the students learn the normal operation of the instruments and where they can observe the characteristics of the physiological signals that are acquired. These laboratory activities, shown in Table 4, will complement the traditional experiences in which the student learn how to inspect, maintain, troubleshoot and repair the equipment.

Clinical engineers also have increasing responsibilities in acting as technical experts assisting the clinical staff in the acquisition of new equipment. It is necessary for the students to develop their critical thinking skills by evaluating technical documentation of products, with special emphasis on understanding equipment specifications. This is done by introducing exercises in the curricula in which the students need to identify the strengths and weaknesses of different models of equipment for a given function. The analysis of the technical specifications of pacemakers, where the students need to compare units in which the specifications have been obtained in different conditions and consequently cannot be directly compared, is an example of such activities. The involvement of clinical engineering in the visits for the accreditation of their hospital is another issue that is increasingly becoming a fundamental role of the profession. Students need to know the role of local, state and federal regulatory agencies, their areas of responsibility and the documents that they issue. Because of the language that they use, reading and understanding standards is not an easy task, especially for students without experience in this kind of documentation. BET students are then exposed to the most common standards concerning technical aspects of healthcare facilities under the guidelines of the faculty, to later carry out personal work focused on reading, understanding and presenting selected standards to their peers in a plain language and focusing on their key aspects.

The students enrolled in the BET program are also exposed to different computer applications in addition to the traditional computer classes. Our approach includes the extensive use of e-mail as a communication tool normally used in industry and from which the students have little exposure before entering college. E-mail is routinely used by the faculty of the BET program to communicate with the students and by the students to submit exercises and reports. The students are also required to subscribe to the technical distribution lists described in the previous section. The use of the Internet as a tool to obtain information on clinical equipment is also part of the exercises designed to broaden the student computer skills. These are complemented by the use of Intranet services that allow the students to work asynchronously on a common project such as the analysis of different AAMI Standards, the interpretation of policies from the Clinical Engineering Department of a hospital and to write reviews of articles with a group consensus [11]. Students also experiment with standard packages for clinical engineering, such as ones that keep track of inventory, or schedule regular and emergency repair work and preventive maintenance.

SELF-ASSESSMENT OF THE BET PROGRAM

Student surveys

Student surveys are routinely used to assess the impact of the Guest Lecture Program on the BET students as well as to measure their level of self-confidence before entering the clinical internship. A summary of the questions asked of the students

Table 4. Laboratory experiments in the BET program. The laboratory experiments are balanced between some that focus on the basic concepts of measuring physiological signals and parameters and some others where the students work with real clinical equipment.

Laboratory work in the BET program	
Fall semester	Spring semester
1. Introduction to medical equipment	1. Differential and Instrumentation Amplifiers
2. Introduction to soldering	2. X-Ray simulator
3. Measurement of DC and AC skin impedance	3. ECG performance and testing
4. The electrical safety analyzer	4. An EEG filter
5. Characterization of transducers	5. Bedside monitoring systems
6. Fundamentals of the Wheatstone Bridge	6. Characterization of pacemakers
7. An electronic thermometer	7. Characterization of defibrillators
8. Basic circuits based on Op. Amps.	8. Characterization of electro-surgical units

regarding the use of interactive videoconferencing in their Guest Lecture Program is as follows:

- List how interacting with professional in College will benefit your future career.
- Name the most interesting lecture in the Guest Lecture Program.
- Describe the characteristics that made that particular lecture to be interesting.
- Name the lecture that you think will have the most impact in your future career.
- Name the less interesting lecture in the Guest Lecture Program.
- Describe the characteristics that made that particular lecture to be the less interesting.
- How could that lecture be improved?
- Do you think the Guest Lecture Program was well balanced between technically in-depth lectures and lectures aimed to increase your breadth of perspective?
- Give an overall evaluation of the Guest Lecture Program.

The analysis of the 11 student responses indicates that all of them prefer lectures with a strong technical content rather than lectures focusing on interpersonal or interprofessional skills [12]. Students identify the main benefits of the program as the opportunity to acquire more in-depth technical information on medical equipment, followed by the possibility of interacting with professionals in the field. The students also highly value the opportunity to be aware of the industry needs and to talk with the professionals currently employed in the field.

They also feel that the use of videoconferencing has some drawbacks [12]. The main disadvantages of using videoconferencing are:

- it seems that the students at the near end benefits most by receiving better attention from the speaker and having the opportunity to experiment with the equipment that the speakers bring for demonstrations;
- in distant learning, the personality of the speakers and their ability to engage a remote audience become key factors in the success of a program delivered remotely;
- the number of videocameras, their resolution and placement in the classroom are critical to determine the success of a distant learning activity [13].

Table 5 shows the surveys that the students take before and after the clinical internship. The goals of the survey before the internship are to assess the level of student self-confidence in their ability to carry out tasks of clinical engineers and to identify the areas in which the students feel more or less prepared. The survey after the internship is used to measure how their technical skills improve and how the students perceive the profession of clinical engineering after their first contact with the profession. The survey also asks the students to identify the most and least satisfactory work that they did during the internship and how the curricular contents of the BET program are useful in their first practice of clinical engineering. Students in general feel well-prepared before the internship although the personal strengths that they identify are very different among them, ranging from having a good basic knowledge of the profession, to personal initiative, ability to read technical documents and good mechanical skills for example. Their main weakness is their limited hands-on experience with medical equipment and their difficulties troubleshooting complex systems.

Once it was completed, all the nine students involved in the internship responded to the survey regarding this experience. The results indicate that all of them had a marked improvement in their technical skills as a result of their work in the different services of the hospital. The students indicate that the most satisfactory work is solving technical problems in medical equipment, while the less satisfactory tasks are servicing older and outdated equipment, doing routine preventive

Table 5. Summary of the students surveys after completing the regular courses (pre-internship) and after completing the clinical internship

Clinical Internship Surveys for BET Students	
Pre-internship survey	Post-internship survey
Name reasons why you chose the BET program	Name the most and less satisfactory work performed during the Clinical Internship
Have your expectations of clinical engineering changed during these semesters? Why?	What were your strengths and weaknesses coming into the internship?
What are your expectations for the Clinical Internship?	After your internship experience, how would you change the BET program?
What do you perceive as your strengths before going to the Clinical Internship?	Did the internship change your perception of clinical engineering? How? Why?
What kind of job or industry in clinical engineering seems more appealing to you?	What kind clinical engineering job or industry would you like to have?
Where do you expect to be in 1 year?	Evaluate how the clinical internship has changed your technical and interpersonal skills
In 5 years?	Evaluate the level of interaction with clinical engineers and clinical staff

maintenance and cleaning the instruments. The students responded that an additional and valuable outcome from their experience was to have a clear vision of the reality of the profession, to have realistic expectations regarding the hospital environment and a better understanding of the current problems in clinical engineering. During the internship the students realized that the clinical community professionally respects clinical engineers in the healthcare field although their work is largely unknown by the general public.

Contact with clinical engineering supervisors

Although the faculty keeps frequent contact with the student supervisor via telephone, this is complemented with personal visits from the instructor to the students and their supervisor in the hospital. These visits allow for the building of a personal relationship with the supervisors as well as to follow the students during this time. They are also useful to evaluate the adequacy of the curricular contents of the BET program to the needs of that particular hospital and receive important feedback from the clinical engineering manager in a relaxed atmosphere. It also serves to identify those topics that will be critical to clinical engineers in the near future, in order to incorporate them into the BET program. The instructor can assess the level of involvement of the students in the activities of the clinical engineering department and evaluate how they adapt to this workplace environment. Finally, the personal contact with the clinical engineering manager is useful to evaluate the needs regarding their technical personnel of different hospitals depending on their geographical settings, as they are different between large cities and rural areas.

Student internship daily log

During the internship period the students are required to complete a daily log that summarizes their activities in the hospital. The main purpose of this daily log is for the BET faculty to ensure that the students are rotated through the different services in the hospital and exposed to all the medical equipment for which the clinical engineering department has responsibilities. However, the analysis of the students' daily log is also extremely useful to detect in which areas they are more or less prepared as they indicate in the daily log the assignments and tasks that they felt more comfortable with, and in which ones they required additional help from experienced technicians. This allows for modifying the curricular contents if a deficiency is shared by a large number of students. For example, during these last years the BET program has included mammography systems, more topics on lasers in the clinical practice and introduction to networking concepts to service modern Intensive Care Units (ICU) that are linked to a central station. The daily log is also a useful tool to monitor the progress of the students through their internship period, measuring how they undertake tasks with more responsibility as the managers and the students themselves feel more confident on their skills. Finally, it is a good introduction to work documentation which is important in the practice of any engineering field as it is critical do document who did what, when and how [14].

Internship supervisor surveys

Once the internship is finished, the supervisors of the students are asked to evaluate their performance and to respond to the survey shown below. The supervisors are asked to evaluate the student performance, as well as to express their opinion on subjects related to the field.

- Evaluate the student regarding his/her preparation.
- Evaluate the student regarding his/her development during the internship.
- Evaluate the student regarding his/her professional attitude.
- Evaluate the student regarding his/her ability to work without supervision.
- Evaluate the student regarding his/her willingness to learn.
- Evaluate the student regarding his/her initiative.
- Give an overall evaluation of the student.
- Evaluate the student relationship and interpersonal skills with other clinical engineers and clinical staff.
- Compare this student's performance with other interns with similar backgrounds.
- List the most important qualities for clinical engineers.
- List the areas where the student had more difficulties.

The responses analyzed in this paper come from 9 different supervisors at 9 different hospitals. Each hospital has its own policies and regulations regarding how the students are supervised. Normally, each student is assigned to a senior engineer in a major area such as clinical laboratories, operating rooms, imaging, etc. However, it is not uncommon for the supervisor to be completely responsible for the student work and progress. These supervisor surveys are useful to assess the performance for the BET program graduates, as they can identify in which areas the students are best prepared and in which ones some improvement is needed.

The supervisors agree that the internship experience is a key benefit for the students as they have the opportunity to work with large scale equipment, such as X-ray machines, MRI imaging systems and lasers that cannot be experienced in academia. They also recognize that in this period the students are able to observe how industry works, learn what the major concerns and problems in the field are, and have a clear idea about what will be expected from them in an entry-level position. The most important qualities for a technician, according to the supervisor responses

are: technical ability, ability to work with clinical staff, motivation, communication skills, computer skills, customer service skills and common sense. According to the supervisors, the BET program prepares the graduates at an acceptable and competitive level. There is, however, room for improvement especially in the areas of troubleshooting, phone skills, knowledge of regulatory agencies and effective time management skills, although they recognized that it is based mostly on experience.

Contact with students after graduation

Keeping in contact with students after they graduate is useful to assess the status of an academic program. The number of job interviews, the total number of offers for graduates and the compensation figures for entry-level positions are parameters that indicate the state of the BET program. But this close contact with students during this time is not only a useful assessment tool, it is also appreciated by the students. They are mostly inexperienced in the process between sending out resumes and being hired by a company. Faculty can offer their expertise in issues such as interviewing, follow-up calls, professional appearance as well as providing input in their evaluation of different job offers.

CONCLUSION AND DISCUSSION

This paper describes the approach developed by the author in the Biomedical Engineering Technology Program at the Wilkes-Barre Campus of Penn State University. In the two and a half years since its implementation, this approach has proven to have a very positive effect on the graduates of the program, as is shown by the positive feedback from industry where the graduates work, their placement rate and the high number of job offers for each BET graduate. In particular, the BET graduates at the Wilkes-Barre Campus of Penn State have a 100% placement rate with 4 to 5 job offers for each student.

Despite its success, the implementation of new academic activities is not a road without obstacles. First, it requires an extensive use of technological tools that are not yet very often experienced in Engineering Education. The problems in their use range from merely technological aspects such as the video compression and audio delay in interactive videoconference, to the time that is required by the students to learn and be familiar with the different technological tools in order to use them satisfactorily. Students need to learn the operation of these tools as well as use them for their engineering assignments. As faculty, we do not have extensive experience in the use of new technological tools in the classroom, so we must be ready to respond to possible drawbacks and failures [11]. Furthermore, students may be reticent to actively participate in the different activities described in this paper, as they are not accustomed to this holistic approach. It is then necessary to emphasize from their first day in the classroom the importance as well as the reasons and objectives underneath each activity. Moving from a teacher-centered to a learner-centered approach is not an easy or immediate task and will only succeed if the faculty can engage their students in active learning.

The basis of this curriculum is to present the Biomedical Engineering Technology not like a series of different courses that the students need to take in order to graduate, but as a set that shares a common vision. In this way, the students are introduced to the profession of clinical engineering from their first contact with the BET program. This approach puts an additional workload on the faculty as the different activities have to be planned well in advance as they interact with each other, although the positive results obtained counterbalance this additional work.

A Biomedical Engineering Technology program not only needs dynamic and knowledgeable faculty, but also a strong support and commitment from their administration. Traditionally, these programs have enrollments that are lower than other engineering technology programs in the same location, that can be as low as three students in a particular semester. These numbers can be erroneously perceived by inexperienced administrators as a program failure, especially in today's enrollment-driven budgets. Administrators need to understand the need for specifically-focused academic programs, that serve unique industry and social needs in which success is primarily measured by the market. The enrollments in BET programs, as well as other engineering technology programs are strongly dependent on the socio-economic conditions in the geographical area they serve, experiencing increases and decreases more abruptly than other more traditional academic programs. In any case, the final evaluation of an academic program is done by the market, which in the case of the program described in this paper has been extremely positive since its implementation

This paper has described innovative approaches in engineering technology geared towards a learner-centered education. Most of the academic activities are geared towards student-centered learning approaches and can be easily translated into other engineering technology or even engineering programs. These approaches are not the only ones that aim to move engineering technology education to higher levels of success. There are other academic institutions that offer other innovative approaches in their engineering technology programs to make them ready for the next century [15], innovations in distance education delivery [16] and by the use of the new information technologies [17] for example. It is the responsibility of each institution and the faculty involved in

these programs to decide which one of these current or new approaches suits better the mission and goals of their institution.

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