Biomedical Engineering as STEM Education in Georgia and New Chalenges for Internationalisation of This Process

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Abstract
This paper presents some aspects of developing STEM education in Georgia, and internationalization of this process by preparing Biomedical Engineering Program for ABET accreditation. Methodology for using Project courses for assessing a number of ABET outcomes. In the advent of EC 2000, Engineering programs have grappled with methods for assessing some of the ABET outcomes, especially those skills which are not taught in the traditional engineering programs. Team and Capstone Design courses taken by IV year in the Georgian Technical of Engineering over a two-semester period. Each course is team-taught by professors in Biomedical Engineering Departments consisting of Biomedical engineering Program Student teams. The capstone design courses are used to assess ABET 1-7 outcomes. Students’ abilities in these outcomes are quantitatively measured using outcome specific project related lectures and assignments given throughout the semesters. The methodology discussed in the paper has made it possible to identify problems encountered by students in these outcome skills, thereby, facilitating adjustment in course content and delivery, and formulation of plans to assist students to improve on these skills. Education specifically related to scientific research, technology, engineering and mathematical disciplines (STEM) are the best measure for increasing Georgia's economic prosperity interests.

Keywords: STEM, Biomedical Engineering, Education, Assessment

Introduction

European countries and period from 1995 to 2019, we found significant contribution by STEM educated workers to output growth. Contribution to output growth by tertiary educated employees and the outcome of the investment in research and development in the high-knowledge manufacturing and knowledge-intensive services were above all sectors' average. This is relevant as output and employment growth in these sectors surpass the same in other sectors, therefore contributing to higher income per persons and GDP growth. As STEM skills and investment in research and development have positive impact on GDP per person growth.

The fourth Industrial Revolution (the industry 4.0) is the currently fast-growing and rapid development of digital technologies in STEM fields.

At the tertiary education level, countries have focused attention on their population's preparedness for a rapidly changing, globally interconnected world requiring increased scientific literacy, and high-level STEM research skills. Accordingly, participation in tertiary education STEM disciplines has been closely monitored, as have efforts to increase graduates' transferable skills and to develop curricula responsive to industry needs. Science and technology advances have encouraged a reimagination of the future world of work, and the place of disciplinary knowledge in preparing for this. Participation in broadly defined STEM disciplines, including engineering, sciences, information technology, health, and agriculture, varies by country/territory and region, over time.

For the period 2011 to 2015, participation was highest in some Western European (Finland, Germany, Sweden, United Kingdom) and East Asian (South Korea, China) economies, as well as Singapore. Comparatively, the United States and Australia lagged behind (UNESCO Institute of Statistics [UNESCO], 2018; Ministry of Education of the People's Republic of China, 2015). Large numbers of tertiary education students enrolled in these STEM programs are located in the three largest higher education systems, that is, China, India and the United States (UNESCO, 2018; Ministry of Education of the People's Republic of China, 2015).

Over the period 2011 to 2015, participation remained relatively static in most countries across the STEM disciplines however, there were some exceptions. Enrolments in natural sciences, mathematics and statistics tertiary education programs increased in the United Kingdom, India, and France. At the same time, enrolments in information communication technologies increased in Brazil and Israel, and enrolments in agriculture, forestry, fisheries and veterinary increased in Brazil. Greater volatility was recorded in engineering, manufacturing and construction, where enrolments dropped marginally in Brazil and Finland, and considerably in India, while increasing in Norway (UNESCO, 2018).

MCC's (Millenium Corporation Chalenges) Georgia II Compact (2013–2019), funded the STEM Higher Education Project, which aimed to improve science, technology, engineering, and mathematics (STEM) university education to give graduates better employment opportunities with higher incomes, leading to an increase in economic growth of Georgia. Three public Georgian universities and one university from the United States worked to give Georgian students an opportunity to earn a high-quality STEM bachelor's degree, improve the Georgian partners STEM-related infrastructure, and prepare the partners for international program accreditation. nicate, analyze and use the information to face the uncertainty of the future.

What is main motivation for STEM education? -related jobs are on the rise. Workers are required to exercise critical thinking and decision-making skills while being knowledgeable and competent in domains related to Science, Technology, Engineering, and Math (STEM). The exploring the Future of Innovative Learning Environments Workshop, hosted by the Georgian Technical University in November of 2018, allowed stakeholders to make informed decisions about the adoption and use of innovative learning environments (ILEs) in higher STEM education. Participants had the opportunity to consider four emerging technologies that could assist in this effort: personalized and adaptive learning, multimodal learning formats, and artificial intelligence and machine learning. The research team gathered shared ideas through online meetings and collaborative activities that reflect on the opportunities and challenges to expect while implementing ILEs in higher education STEM curricula. Since these immersive technologies are quickly evolving, it has been challenging for institutes to implement integrated STEM education programs that utilize them.

Qualifying Biomedical Engineering Program for ABET Accreditation

The ABET Foundation has a contract with MCA-Georgia to provide information relative to the readiness of selected STEM programs at public Georgian universities for a review by ABET for possible program accreditation. Among them was Biomedical Engineering Bachelor Programa which is implemented in Georgian Technical University.

Programs that are accredited by ABET (formerly the Accreditation Board for Engineering and Technology) have been thoroughly evaluated and found to meet agreed-upon quality standards for the engineering profession. The organization only offers specialized accreditation for engineering, computing, technology and applied science programs.

ABET requires that engineering programs have a continuous improvement process in place that leads to program improvement based on the assessment and evaluation of the level of attainment of student outcomes.

Despite significant reforms, important gaps remain. Georgia lacks sufficient science, technology, engineering, and mathematics (STEM) programs to sustain strategic STEM fields of study and research and to fulfill the demands of the labor market. The Soviet legacy of highly centralized control over the education system has prevented greater synchronization between the Georgian market demands and higher education offerings. In addition, when it comes to STEM education, significant gender gaps still exist: Female students represent only about one-third of all students enrolled in STEM-related fields of higher education. Finally, if the opportunity is available to them, many young Georgians prefer to be educated abroad, and those with the best skills also tend to seek employment abroad. To address these challenges, the Millennium Challenge Corporation (MCC) made a major investment aimed at facilitating high-quality inclusive university-level STEM education in Georgia. Through this investment, San Diego.

State University (SDSU) partnered with three Georgian public universities—Tbilisi State University (TSU), Georgian Technical University (GTU), and Ilia State University (ISU)—to offer SDSU's U.S. bachelor's degrees in a range of STEM disciplines to Georgian students. The primary goal of this effort, the Georgia II STEM. Observations in this introduction are drawn from the evaluation solicitation (MCC, 2018b), the monitoring and evaluation plan (MCC, 2018), and our interviews Higher Education Project is to develop a system to assure and enhance the long-term delivery of high-quality STEM bachelor's degrees in Georgia. The

Project has also aimed to increase capacity of the Georgian public universities to offer internationally accredited programs.

Figure 1: Units for preparing BME Program for ABET accreditation

Background Information and Student Admission

The development of such a process by the GTU BME program has provided to a faculty membera as stated above will be required to develop such a process and to implement it.

At the Georgian Technical University (Georgian Polytechnic Institute) the Department of Biomedical Techniques was established in 1983. To stay in tune with the fast pace of innovative technologies in the field, the increased demands on medical technology specialists and the worldwide trends in the implementation of educational programs in this area, a new undergraduate educational Georgian Language Program -"Biomedical Engineering" was prepared in 2013, which received accreditation by the Georgian Educational Programs Accreditation Council.

A new English language program “Biomedical Engineering” was authorized in 2013 by National center for Educational Quality Enhancement of Georgia, and it has been implemented since 2014, with the first graduates from this program in 2021.

Currently the Biomedical Engineering programs are implemented in two independent programs: Georgian Language and English Language and submitted for potential ABET accreditation. The program is administered within the Department of Biomedical Engineering of the Georgian Technical University Faculty of Informatics and Control Systems.

Both programs, Georgian and English Language, are offers degree “Bachelor of Science in Biomedical Engineering.” During the fourth year, Students in the Georgian Language Track select a specialization in either Medical Computer Systems or Medical Informatics.

Generally, the classes are offered during days on campus. Sometimes, we offer one or two sections of a course that has multiple sections in the evenings. The classes are lecture classes or lecture-lab classes. We also develop on-line content for all courses by using Zoom – Cloud platform for video lectures and webinars. Clinical engineering practice is implemented in hospitals where students will do their clinical internship, 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.

Higher education in Georgia is regulated by the Laws on Higher Education, on "Education Quality Enhancement" and other sub-legislative acts. Georgian students who have passed the Unified National Examinations may enroll in a state accredited program at an accredited higher education institution, based on the ranking of scores he/she received at the examinations.

Only holders of the state certificates confirming full general education or persons equalized with them have a right to study in undergraduate programs. The Unified National Exams are the precondition for admission to undergraduate programs.

Holder of a state certificate of complete general education or a person who has passed the Unified National Examinations and gained the right to enroll in the Georgian Technical University (hereinafter - GTU) in accordance with the rules established by the legislation of Georgia has the right to study in the bachelor's educational program of the GTU.

In order to be admitted to the Biomedical Engineering (BME) program at GTU a student should pass mathematics along with other exams organized by the National Assessment and Examinations Center (NAEC) through "Unified National Exams" and receive enough scores to be admitted to the Faculty of Informatics and Control Systems (FICS). "Unified National Exams" provided through Computer Adaptive Testing (CAT) are created by the experts of NAEC.

Student Outcomes

Before graduation, students of the Georgian Technical University's Biomedical Engineering programs will demonstrate:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The plan of study for students in the program including information on course offerings in the required curriculum in the form of a recommended schedule by year and term along with maximum section enrollments for all courses in the program over the last two terms the course was offered. Apart from acquiring discipline specific knowledge, the curriculum requires that graduates have sufficient knowledge of calculus, physics, statistics, chemistry, biology and differential equations as well as an ability to apply this knowledge to the understanding of the core Biomedical Engineering concepts, including the analysis, design and realization of such concepts. The students are also required to be sufficiently familiar with computer applications for Biomedical Engineering in addition to developing professional, life-long learning, and ethical skills required by professional environment.

Laboratory instructions and design components play important role in Biomedical Engineering education. Therefore, it is important to ensure that the undergraduate courses are accompanied with extensive design experience and carry out laboratory works in order to provide the students with sufficient practical experience in the various fields of Biomedical Engineering. Hence, the department has always been concerned with the development, updating and modernization of its laboratory facilities. An important component of the curriculum are Project embedded courses, Team Project and a Capstone Design Project. The Capstone Design Project is intended to culminate the skills of the BME undergraduate degree. The students are required to take the course and complete the project in their senior year (last semester). During the Capstone Design Project course, the students gain valuable exposure to various types of activities involved in Biomedical Engineering.

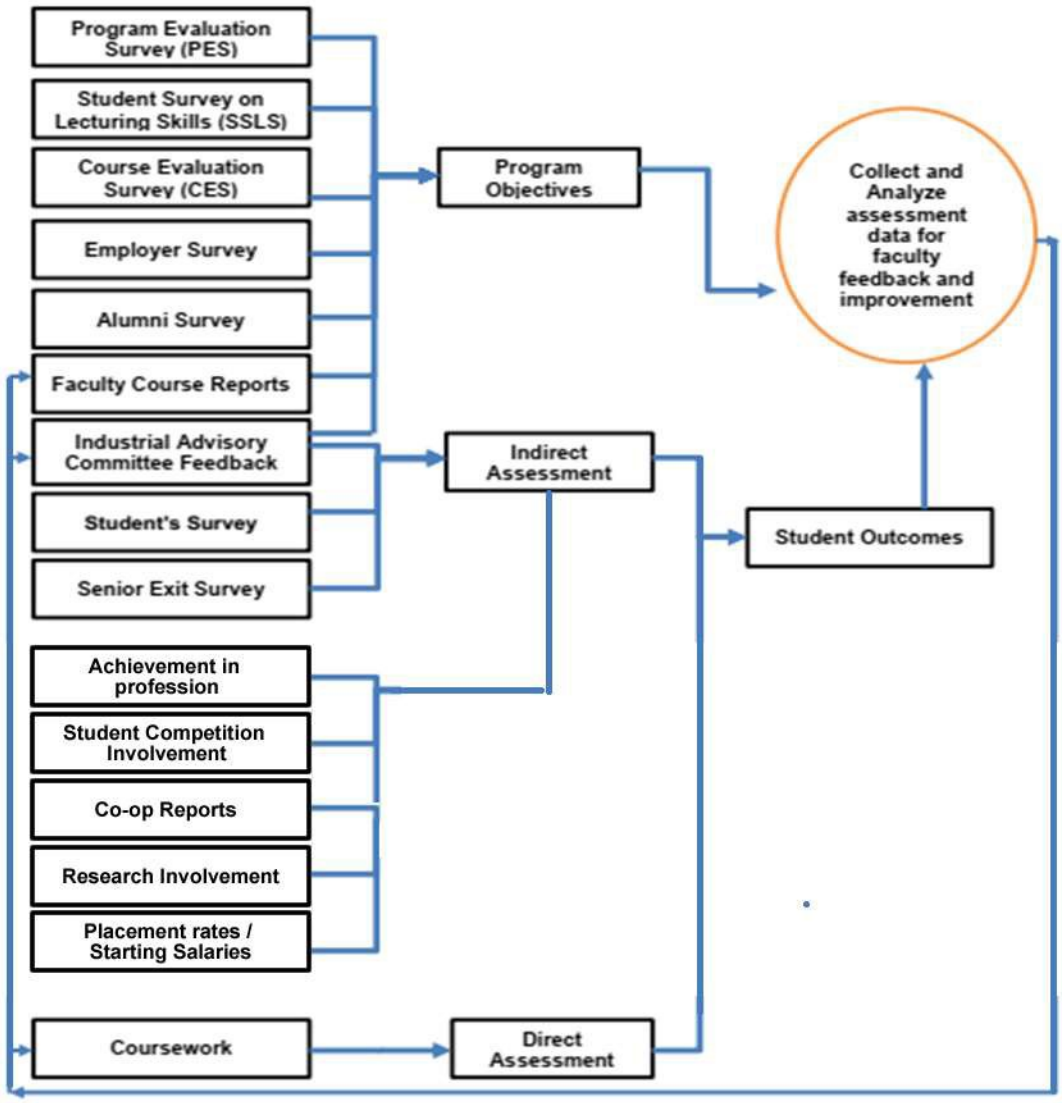

Figure 2: A summary of tools for assessment and evaluation process

Assessment and Evaluation

At the end of each year, the department carries out a survey of its graduating students. The survey sought to find out how the students evaluate the SOs for the program. The questions in the surveys assessed graduating students' satisfaction in their preparedness for each of the SOs they have encountered before graduation. The survey results are shown in Figure 3.

Figure 3: Exit survey results of the final year students, academic year 2020- 2021

Figure 3 represents the exit survey results of the final year students based on a-k ABET student outcomes, which was transferred to new outcomes -1-7 for the followed academic years. The results show that the students believe that their level of knowledge of all student outcomes are satisfactory and were above 70% criteria set by the department.

The Biomedical Engineering Department has adopted a benchmark level of attainment of an average score of 3.5 on a scale of 5. For an outcome to be considered to have been attained by a student, at least a 70% average score must be achieved as evidence illustrating that the level of the student outcome achievement is satisfactory. Similarly, at least 75% of students must achieve this benchmark value.

The process of direct assessment of Student Outcomes is carried out by using combinations of course work such as quizzes, exams, projects, presentations, homework, etc. Where the achievements on these exercises are directly tied to program outcomes. Let us describe the direct assessment of a course say.

During the semester, he selected various assessment tools and their relative weights as shown below in Table 4-3. The students' actual achievements in this course are given in Table 4-4.

Table 1: Assessment Tools for Clinical Diagnostic Laboratory Systems
English Language BME Program

Assessment Task	**ABET Students' Outcomes (SOs)**		
	1	**2**	**5**
Assesment Task	**1**	**2**	**5**
Quizzes (12)		4	8
Assignment(9)	9		
Pract(9)		3	6
Midterm Exam (30)	7.5	7.5	15
Final Exam (40)	10	10	20
Total (A)	**26.5**	**24.5**	**49**

Assesment Task	**1**	**2**	**5**
Quizzes (12)		**2.47**	**4.95**
Assignment(9)	7.3		
Pract(9)		2.38	2.38
Midterm Exam (30)			
Midterm Exam (30)	7.25	7.25	14.5
Final Exam (40)	6.7	6.7	13.4
Total (B)	**21.25**	**16.33**	**30.28**
	0.801887	0.666531	0.618

Achievement = B/A (%) 80, 66. 61.8

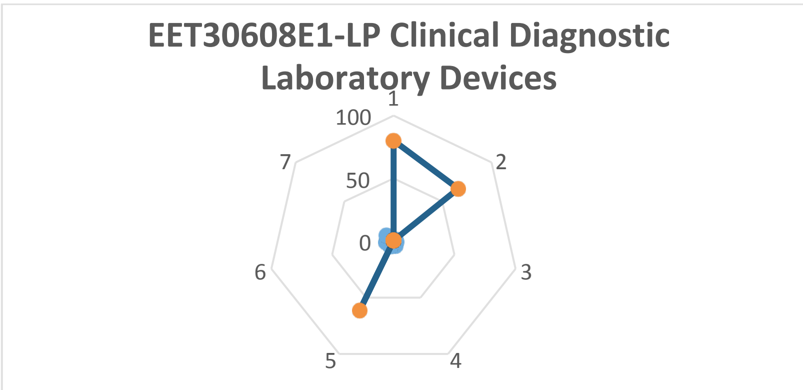

Figure 4

Capstone Projects and Team Projects

In this paper we also present a methodology for using Capstone Design Project, Team Project and other Project Embedded learning courses for assessing a number of ABET outcomes. In the advent of EC 2000, Engineering programs have grappled with methods for assessing some of the ABET outcomes, especially those skills which are not taught in the traditional engineering programs.

Capstone design courses and Team Project, taken by seniors in the BME program over a two-semester period. Each course is team-taught by professors.

Depending on the type of projects selected, student teams could be interdisciplinary, or discipline specific. The capstone design courses are used to assess ABET 1-7 outcomes consisting of the ability to: design a system, function on multi-disciplinary teams, adhere to professional and ethical responsibilities, communicate, understand global and local impact of engineering solutions on society, engage in lifelong learning, have knowledge of contemporary issues, and use modern engineering tools for engineering practice. Students' abilities in these outcomes are quantitatively measured using outcome specific project related lectures and assignments given throughout the semester.

The methodology discussed in the paper has made it possible to identify problems encountered by students in these outcome skills, thereby, facilitating adjustment in course content and delivery, and formulation of plans to assist students to improve on these skills. The methodology also makes it possible to document students' performance in these outcomes. The documentation is used to generate outcome specific binders of students' work that are vital forABET accreditation.

This course is important because it provides the student, an opportunity to practice design in a way that parallels what will be encountered in professional practice. Students are required to apply a systematic design process, incorporate engineering codes, standards, and realistic constraints that include economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political considerations in solving the design problem. In addition, Senior Design Project is the primary course used to satisfy ABET criterion 4 which requires students to be prepared for engineering practice through the curriculum culminating in a major design experience. The latter should be based on the knowledge and skills acquired in earlier course work and should incorporate appropriate engineering standards and multiple realistic constraints. Senior design is also used to satisfy outcome C of criterion 3. This outcome requires students to have the ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health andsafety, manufacturability, and sustainability.

In the Georgian Technical University BME bachelor programm of study takes four academic years to complete, where each academic year is made up of two semesters or terms. Each term is 15 weeks long. All admitted students must follow a prescribed path to achieve their degree. However, duration for completion is not the same for all students. To graduate a student must meet the following requirements:

- Complete a minimum of 240 credit hours (ECTS) of approved course works along with minimum of twelve credit hours of Capstone Design Project
- Spend not less than 45 hours in order to get his/her critical Clinical Practical experience
- Maintain a CGPA of 2.75 throughout the program
- Retake technical courses with grades lower than "C," to meet the minimum CGPA 2.75 criteria (only if he/she is fulfilling all other graduation requirements)

The important part for completing Bachelor Program in GTU is Capstone Design Project, main objective of which is to enable the students to integrate the knowledge gained as a result of pursuing a given degree program in university. The course should enable the students to integrate the skills and concepts learned systematically during their stay at the university. This means that the course content is focuses on refreshing the student's memory on what he or she was taught in class. This helps them to remember the entire content of the degree program and its application.

The students should be able to integrate all aspects of the course which includes the theory, practical skills, and communication skills. They should be in a position to combine the diverse skills acquired in class and apply them in a work environment. This is based on the fact that the ultimate objective of the pursued course is to enable the students to transfer or apply their skills to the challenging work environment.

The courses have main objectives, with each objective related to one of the ABET "1" to "7" outcomes measured in the course, and having a number of anticipated outcomes.

Main Learning Outcomes for Capstone Project

The main Learning Outcome of course are given in Table 2.

Table 2: Learning Outcomes

№	Knowledge and skills acquired as a result of studying the subject
1	**Knowledge and understanding:** Has knowledge for demonstrate the ability to critically, autonomously and creatively identify, formulate and handle complex issues. Demonstrate the ability to participate in research or development work and thereby contribute to the development of knowledge. Has ability to plan with scientific and engineering methods implement qualified tasks within the given limits. Demonstrate the ability to critically and systematically integrate knowledge acquired in central and qualified courses within the program.
2	**Skills:** The student will be able to use the obtained knowledge for solving practical problems on the modern level Apply and understand essential skills, methods, and procedures basic to professional performance in the process of developed and implement new medical devices. demonstrate the ability to present, at the national and international level for the exam, an oral and written account clearly and discuss their conclusions and the knowledge and arguments underlying them. Consistent and multilateral assessment of their own learning process,Determining further learning needs;
3	**Responsibility and Autonomy:** Ability to make judgments on the basis of critical analysis of complex and incomplete information, including recent researches. Understand and be aware of the necessity of clinical devices safety and standard precautions. independently identifying relevant sources of information, conducting information searches, evaluating the relevance of the information, and using correct reference management.

There are two culminating design experiences for BME students in GTU. The Team Project (EET31008E1-K / EET36908G1-K), which is taken in the second semester of the junior year in the Georgian track and first semester of the senior year in the English track), and the Capstone Design Project (EET30908E1-K / EET38908G1-K) which is taken in the final semester of the senior year in both tracks.

Team Project students work in a team, usually of 4-6 students, to develop design specifications, create design concepts, and evaluate them, design the product, and then validate the design through further evaluation. They also consider safety, environmental issues, and the societal impact of their designs in addition to ethics and professional responsibility, as part of the course outcomes. The project selection for each team is a collaborative decision between the students and the course coordinator. At the end of the course, student groups are required to demonstrate and validate their design through a final formal presentation to a committee of BME Department. Students are also required to write a detailed design report, which has sufficient information for manufacturing and users.

The procedure followed for B.Sc. Capstone Design Project is more formal than for the Team Project. The Capstone Design project teams are smaller than for the Team Project, typically being 2-3 students and sometimes even only one student. All BME faculty members provide potential project topics in their fields of specializations to the course coordinator. There may also be projects proposed by a company. These projects are normally presented in one or two paragraph statement. They are designed to be open-ended, thus requiring the students to investigate deeply into the issue to decide what data is needed, what the underlying problem is, and what methodologies are appropriate to apply as analysis tools. The course coordinator announces the project topics to the students, and after some discussion among the students and the course coordinator, the coordinator assigns a project to each team. Procedure for completing and defense for the Capstone Design project is defined by special order of Academic Council of Georgian Technical University. The Capstone Design report is evaluated by a commission of 3 members, which is approved and nominated by the Academic Department by order of the Faculty Dean.

The anticipated outcomes are that students are able to use a systematic design process and modern engineering tools such as solid Modeling in Electronic Workbanch, CAD Systems.

The Capstone design courses in Biomedical Engineering Bachelor Program at Georgian Technical University are intended to provide capstone design experience. The courses draw on the students' skills and knowledge gained from previous years of theoretical and practical classes in mathematics, sciences, engineering science and design. The Capstone design project should be sufficient in scope and technical content to demonstrate the students' technical competence in Biomedical Engineering area of study. The successful completion of senior design project is indicative of the students' preparedness to pursue professional practice of engineering. The following guidelines are provided in the Capstone Design Projects Manual1 to help faculty and project sponsors identify suitable senior project topics:

There are two types of Projects for defense: Individual and Team Projects. For Capstone Projects in general, there are two members in each group.

To ensure active participation of individual members to the group effort, most assignments are first given as individual assignments. It is possible because members are responsible to implement separate part for Capstone Project. For example: Hardware and Software parts, or modeling and construction etc. After grading the individual contributions, the assignment is then assigned as a group assignment.

Essentially every project related to biomedical engineering presents numerous opportunities for students to learn about how constraints influence the design process. For instance, although design of a medical instrument may not be restricted by Regulation (EU) 2017/745 regulatory process, it very likely may be constrained by regulations related to MDE (Medical Devices Regulation) and it very likely may be constrained by regulations related to Occupational Safety and Health (EU OSHA) standards for laboratory safety. Constraints arise naturally through functional, safety, quality, time available, technical, economic, social, environmental, and political requirements and considerations. There must be clear evidence in the Capstone Design project that the constraints that are relevant to the project are addressed.

Similarly, most devices that are constructed use, or should use, appropriate engineering standards for each device. Students are expected to investigate and use appropriate standards in their Capstone Design projects.

Students must discuss both relevant constraints and relevant engineering standards for their projects in the Capstone Design report. This is intended to require the students to think about the constraints that they have encountered in the project, and other constraints that might exist for the project in a different context, and to likewise think about engineering standards in a similar way.

The senior design final report and project demonstration is graded on a 1000 point system. To facilitate easy tabulation of the score in the various outcomes, a spreadsheet version of the rubric is used in the grading.

Conclusions

Global knowledge sharing and innovation development are increasingly important is happening for Georgia. An increasing number of academic programs are chasing various accreditation programs to secure quality and competitiveness. Successful factors can be s ummarized that will be considered whenever the university program seeks ABET accreditation. First, senior management is aware of the importance of international accreditation of the program. Second, program sustainability involves developing sustainable assessments and improving a sustainable process, which is critical and requires sustainable data collection through a process balanced to institutionalize. process efficiency and automation through an efficient management system that automates data collection, data analysis, actions and improvements, cycle closure, and archiving, resulting in reliable and sustained continuous process improvement, which is typically the primary criterion for most program failures.

Faculty participation is important to spread a culture of accreditation and awareness among them with expected outcomes from all toward the program. We found that the commitment of faculty and staff to achieving high-quality outcomes is an important factor in obtaining accreditation. We believe that the approach presented reproduces other programs seeking ABET accreditation. Our approaches represent a comprehensive, continuous process of improvement that can be applied elsewhere.

Obtaining accreditation will promote the continuation of quality STEM programs in Georgia, although more work needs to be done with employers and other stakeholders to raise awareness of the value of these accredited programs in Georgia.

Research-based education is one of the cornerstones of high-quality teaching and learning. Creation and transfer of new knowledge, innovations and technologies. It should become an integral part of the agenda of higher education. In order to promote the integration of scientific research with learning, it is necessary to develop both project-based courses and to refine their assessment and continuous development methods.

Education specifically related to scientific research, technology, engineering and mathematical disciplines (STEM) are the best measure for increasing human capital, innovation and production of workers capable of managing and responding to technological progress that lies at the center of Georgia's economic prosperity interests. Government policy must be revised to sustain accredited programs. Initial discussions started to address changes needed to make the accredited programs.

sustainable and affordable, including the need to allow universities to charge higher than the standard programs, possibly by modifying the model for financing higher education programs in Georgia in general. Financial aid will also be essential for these programs to be accessible to a wide portion of Georgian society in the future.

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