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Project-based Learning with International Collaboration for Training Biomedical Engineers

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Abstract - Training biomedical engineers while effectively keeping up with the fast paced scientific breakthroughs and the growth in technical innovations poses arduous challenges for educators. Traditional pedagogical methods are employed for coping with the increasing demands in biomedical engineering (BME) training and continuous improvements have been attempted with some success. Project-based learning (PBL) is an academic effort that challenges students by making them carry out interdisciplinary projects aimed at accomplishing a wide range of student learning outcomes. PBL has been shown to be effective in the medical field and has been adopted by other fields including engineering. The impact of globalization in healthcare appears to be steadily increasing which necessitates the inclusion of awareness of relevant international activities in the curriculum. Numerous difficulties are encountered when the formation of a collaborative team is tried, and additional difficulties occur as the collaboration team is extended to international partners. Understanding and agreement of responsibilities becomes somewhat complex and hence the collaborative project has to be planned and executed with clear understanding by all partners and participants. A model for training BME students by adopting PBL with international collaboration is proposed. The results of previous BME project work with international collaboration fit partially into the model. There were many logistic issues and constraints; however, the collaborative projects themselves greatly enhanced the student learning outcomes. This PBL type of learning experience tends to promote long term retention of multidisciplinary material and foster high-order cognitive activities such as analysis, synthesis and evaluation. In addition to introducing the students to experiences encountered in the real-life workforce, the proposed approach enhances developing professional contracts and global networking. In conclusion, despite initial challenges, adopting project-based learning with international collaboration has strong potentials to be valuable in the training of biomedical engineering students.

Keywords **– project-based learning, biomedical project, international collaboration**

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I. INTRODUCTION

The training of biomedical engineers while keeping pace with the fast rate of growth due to technological innovations and scientific breakthroughs poses arduous challenges to several educators in the field [1]. The field of BME is the result of the merger between traditional engineering disciplines such as mechanical, chemical, electrical, materials, computer engineering and biology-based life sciences and medicine, as shown in Fig. 1. This merger of has produced great results by improving procedures such as diagnostic testing, surgical techniques, therapeutic methods, and patient rehabilitation and applying quantitative analysis to biological problems.

The multidisciplinary nature of BME creates challenges on the educational front. The nature of BME demands that students keep up with the technological advances and develop multidisciplinary skills and knowledge and apply them to solve biological and medical problems. In general, engineering seeks to analyze the world in order to set constraints and design, while the life sciences work from hypotheses towards explanatory accounts of phenomena. Reconciling these two asynchronous practices requires cognitive flexibility and true interdisciplinary thinking [2].

A cornerstone of BME educational programs is to provide students with valuable real-world experiences which help them develop true interdisciplinary. This may involve BME students working in close collaboration with clinicians, medical interns and professionals involved in healthcare delivery as well as life science researchers and medical researchers in both clinical and research settings [3], [4]. In particular, students should be exposed to product design, development and manufacturing, regulatory requirements, clinical studies and working in a multidisciplinary team environment. A very effective way to provide BME education is to include exposure to the interdisciplinary projects carried out by biomedical companies and medical centers [5]. The impact of globalization in healthcare appears to be steadily increasing which necessitates the inclusion of awareness of international activities in the BME curriculum. Numerous difficulties are encountered when trying to form a collaborative team, and even more difficulties occur as the collaboration is extended to international partners. Agreement of responsibilities becomes very complex and the collaborative project has to be planned and executed with clear understanding by all partners and participants. The objective of the present work is to develop a model for

interdisciplinary project-based learning (PBL) with international collaboration for training biomedical engineers.

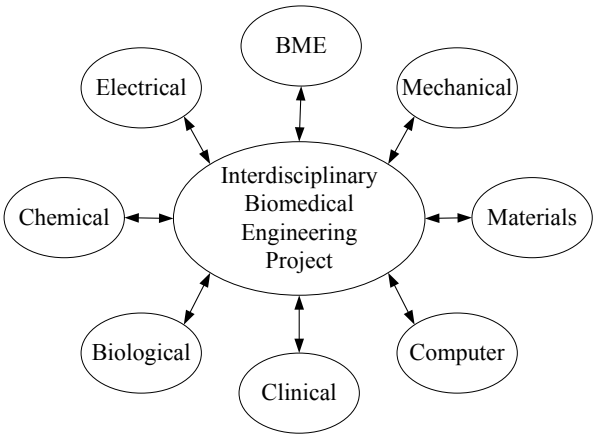

Fig. 1. An interdisciplinary BME project fusing multiple disciplines.

II. Project-Based Learning

An educational approach pioneered over the last twenty years, project-based learning allows students to actively participate in their learning and portrays the correlation with the real-world applications of the subject matter in various courses in the curriculum. PBL has been used in educational settings from teacher education to economics, medicine, business, law, and engineering [6]. Students work on genuine projects in BME to promote active participation, in depth study, and critical reasoning skills. The projects selected are broad-based and allow the students to cultivate free thinking while helping them sharpen skills they will need in their field. Students are broken into small manageable teams to solve these project problems while the administrator acts as a facilitator encouraging the students to probe and research instead of just regurgitate the lessons onto an eventual exam. The main goal of PBL is to create self-directed learners who have strong reasoning and critical thinking skills and become subsequent adapters and life-long learners.

Traditionally, the educational process involves students first learning the fundamentals and then utilizing the knowledge to apply these facts to solve a problem. In contrast, the PBL approach employs the project problems as the driving force for learning and/or applying the multi disciplinary principles that are required to find a solution and provide a context that makes learning the fundamentals more relevant.

Project-based learning is an academic effort that tasks students with producing an authentic work product and by doing so, has them address a range of learning outcomes.

Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a final product- a design, a model, a device, a computer simulation or a process [7].

The project drives the learning required to complete the project. Managing the project requires the engineer to demonstrate effective teamwork, clear communication and the ability to balance the social, economic, ethical, and environmental impacts of the project [8]. Project-based learning is based on the practice of solving problems in the project.

After the students gather data they then begin to weed out the solutions that won't work and narrow down the solution that will, while identifying the critical learning issues as a team. They then research and consult appropriate people independent of the group. Students collaborate and use the skills and knowledge of their fellow group members. The students, keeping a log of their work and actions, discuss the possible solutions to their problem in the project. The outcome and the resulted learning are then presented [3].

In a project-based learning session students should be pushed to learn things that they did not know in order to solve the problems in the project. As the students become more experienced with PBL, they begin to take on the role of the faculty (educator) on their own, posing relevant and tough questions to each other. Studies have shown that PBL students learn considerably more than their peers do in a traditional didactic environment about how to solve problems in the project, manage their own learning and how to work with others [3].

Project-based learning is very well suited to be enacted in engineering schools. It is not designed to replace the existing methods such as classes that focus on design or case studies, but to run congruent with these classes. PBL is different in the fact that it encourages students to be responsible for their own learning and fairly independent of the instructor. Design and case study classes are an integral part of engineering study but they usually rely on applying knowledge gained in a more traditional learning environment.

The PBL approach requires students to push themselves and to evaluate and give feedback on their own solutions and in turn come to their own conclusions. The problem solving process is actual learning, not merely application of knowledge [3].

III. Collaboration PBL Model

A model for PBL international collaboration is proposed as shown in Fig. 2. The potential collaborators can be students and researchers from universities, hospitals, and industries in two or more countries. Project components include designing on conceptual basis, theoretical formulation, working together as a team, adapting technology for collaboration, conducting virtual meetings, executing periodic design review, agreeing on a group decision, conducting a report presentation, conducting experiments, and analyzing data.

The stated goals for project-based learning include the following: Improved problem solving skills, critical thinking skills, and communication skills compared to traditional engineering and science curriculum; An increased ability to

integrate and approximately apply technical skills with the fundamentals of math and science; An increased ability to participate in effective teams; An increased competence in applying technology for effective analysis, design, and communication; An increased motivation for self-responsibility and life-long learning.

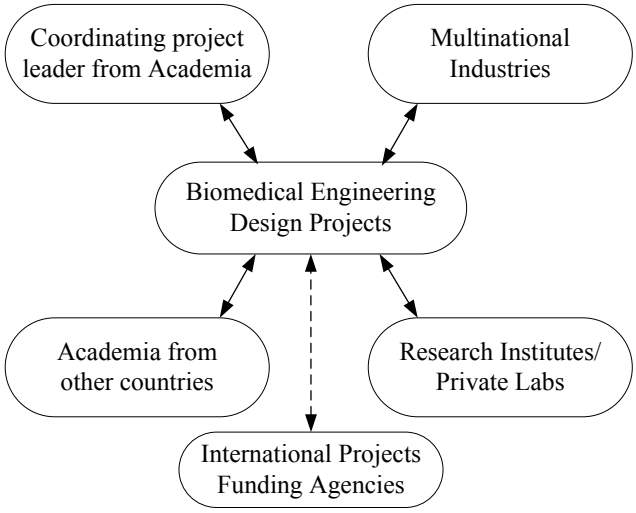

Fig. 2. Categories of potential collaborators for BME projects.

Each PBL experience begins with the students being introduced to set of user defined performance requirements [7], [9]. It is imperative that a clear and concise design objective statement be formulated. From this statement a list of functional requirements can be derived and potential conceptual design solutions are identified. In a collaborative PBL with international participants, the constituent steps are depicted in Fig. 3.

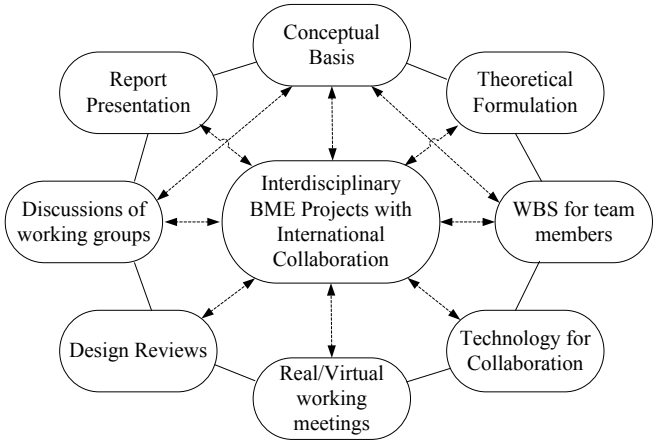

Fig. 3. Constituent steps in collaborative project-based learning.

The project can be carried out in phases distributed among collaborators. Alternatively the project can be broken to sub projects with concurrent work involving collaborators. Potential design solutions are analyzed from a systems level perspective, a detailed design solution is developed and specifications are established that will enable the design to be fabricated. A prototype of the design solution is built and tested to guide students through the process, support teamwork, focus communication and evaluate if the economic objectives are achieved. Throughout this process the students are challenged to work in teams and to practice systems level thinking when integrating technologies.

IV. Results

Several interdisciplinary biomedical engineering projects were carried out previously which involved international collaborations. Many of the projects fit partially into the proposed model, though they were not originally designed along cross linking with the curricular matrix and expected learning outcomes. However, the student learning outcomes seemed to be very positive and conforming to expected goals. The projects were at the graduate and undergraduate levels and some of them are listed below.

- Collaboration in Canada with the University of New Brunswick researchers worked on a project involving digital image processing and quantitative characterization of endoscopic images.
- Collaboration with Universite de Technologie de Compiegne in France on development of detailed documentation for intensive care labor and delivery including physiological data acquisition and networking, and interoperability issues in operating rooms and intelligent interoperable systems for infusion therapy in patient controlled analgesia.
- In Germany, with a Research Institute on a project on biomedical visualization involving 3-d representation of pulmonary networks and navigation modules.
- In Singapore, with a US start-up company, involving research and development of respiratory sounds data acquisition and analysis to add in pulmonary function abnormalities, and with US collaborations on projects involving telemedicine applications for home healthcare for high risk patients.
- In China, with researchers from Tsinghua University on a project involving signal processing of maternal and fetal ECG.

In the case of the aforementioned collaborative projects, the scope, duration, participants, funding, and intended outcomes were quite varied. The process of initiating, formulating and executing collaborative projects is very challenging. In addition to commitment by participants including faculty, students and industry partners, support by management and resource allocation are essential for meaningful collaboration. The consequent results were also varied with generally positive outcomes. It is felt that the projects were successful to some extent. They certainly achieved several important learning outcomes of teamwork, ability to apply theoretical principles from multiple disciplines, effective communications, creative problem solving, and awareness of the importance of globalization especially in the biomedical engineering field.

V. DISCUSSION

The proposed PBL model with international collaboration will yield numerous advantages to all the participants: students, faculty, researchers, administration, health care providers, and others. On the other hand, it should be noted that there will also be several challenges in the implementation of PBL. One important part of PBL is the project definition and problem statement. Students are more responsive when they perceive the project to be real, complex, and challenging instead of an extension to classroom exercises. The projects must be designed to curricular requirements to make sure that all desired curricular objectives in terms of student learning outcomes will be met. These projects are usually aimed at real life problems in industry to give the students interesting work that truly applies to the BME field. It is also required to formulate a curricular matrix to ensure that the projects integrate well with the required theoretical and practical subject material covered in other classes. The multinational project team leaders must closely monitor the progress of the students, pose relevant questions, and provide mentoring to help the students reach their end results. The project goals and scope may need to be revised to avoid any ambiguity. The expected student learning outcomes may have to be refined based on real outcomes taken into account the difficulties encountered in the execution of the project.

It is anticipated that creating a presentation and presenting their findings and solutions at group meetings would be a motivator. Some competition among collaborators for timely and efficient completion of their tasks can be healthy. There has to be a clear understanding and appreciation of the efforts of all the collaborating group members.

The projects can be carried out in different formats. Continuation projects with iterative refinements will generally tend to yield positive outcomes and successful executions. When verifying the design solutions and prototypes, meaningful testing with appropriate groups is essential.

Another big challenge in developing and executing a project with multiple collaborators is deciding how the project work break down structure (WBS) is formulated and how the faculty load distribution is agreed upon, considering the international nature of the collaborators. During the initial projects these factors are very difficult to formulate a priori in an optimal fashion. However, after a few interdisciplinary international projects are completed with at least some partial success, the subsequent project selection, team formation, scope definition, WBS, monitoring, mentoring, and control can be continually improved to give better results. Substantial multi-national experience in academia, industry and government triggered the interest in the design of the proposed model for PBL with international collaboration. Relevant experience has helped greatly in the development, execution, and oversight of the collaboration projects. A few new PBL projects in Biomedical Engineering involving undergraduates with collaborators from hospital/device industry are in the planning stage.

VI. CONCLUSION

The students and educators in biomedical engineering can benefit greatly from the training programs which include the proposed project-based learning approach coupled with suitable international collaborators from academia, medical device industries, research institutes, and health care delivery organizations. In conclusion, despite initial challenges, the model of interdisciplinary PBL with international collaboration can play a very vital and beneficial part in training future biomedical engineers.

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