Cooperative Education Model for Biomedical Engineering Program: A Case Study in Southeast University and Beijing Genomics Institute

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ABSTRACT

By using case study method, this research examines the SEU-BGI cooperative education model. What is the co-op model and how the model works in BGI are the two research questions. Materials were collected from multiple sources. Results show that the SEU-BGI cooperative education is comprehensive in mission and goals, institutional and structural commitment, learning outcomes, curriculum plan, activities, monitoring and assessment. We also discuss the attributes, principles, characteristics, components and educational value of this case that contributing to the learning effectiveness. This paper provides the empirical basis and case reference for the Chinese National Excellent Engineers Education Program.

Keywords: Cooperative education, Engineering education, Work-integrated learning, Experiential learning and Case study

1. INTRODUCTION

A. Backgrounds Information

In engineering education, the employers of the industrial sector is one of the important stakeholders of curriculum reform, and it is vital for engineering education that teaching, research and practice are closely integrated. Therefore, Cooperative education is effective way to connect academic learning and work experience tightly.

Cooperative education (co-op) has been an option in higher education for about 100 years since co-op engineering programs was launched at the University of Cincinnati in the United States in 1906 and at the University of Waterloo in Canada of 1957, which were in part inspired by the sandwich programs that may have existed in the United Kingdom since 1840.

In China, the National Excellent Engineers Education Program (NE3P) is being implemented now, aiming to transform scientific-focused engineering education to one that returns to engineering practice, and thus requires curriculum reform through cooperation between universities and industries.

B. Definitions of Cooperative Education

The terminology of "cooperative education" was first used by professor Herman Schneider, who initially established the program to bridge the gap between theory and practice in engineering education. After years, a number of definitions have been suggested by organizations, such as American National Commission for Cooperative Education (NCCE), Cooperative Education Division of American Society of Engineering Education, Canadian Association for Cooperative Education (CAFCE), and The World Association for Cooperative Education, etc.

In this paper, we adopt the definition by the American National Commission for Cooperative Education who defines cooperative education as "a structured educational strategy integrating classroom studies with learning through productive work experience in a field related to a student's academic or career goals" [1].

C. Literature Review and Research Questions

In the research field of cooperation education, in addition to the definition, there are several key literatures discussing the wide academic themes. These

research topics are, for example, specific outcomes of cooperative education, co-op as a model for authentic assessment of student learning outcomes[2], the role of organizational and individual factors in enhancing co-op effects[3], cooperative education should demonstrate its true experiential learning and value beyond just the experience from work[4], the correlation between industrial placements and degree performance in co-op model[5], and multiple levels of co-op assessment in curriculum innovation[6]. These literatures provide a broad perspective and solid foundation for this study.

The objective of this research is to identify and explain the model of cooperative education implemented in engineering education in China. Research questions are:

1) What is the cooperative education model implemented in Chinese university, including institutionalizing, faculty involvement, student involvement and employer involvement?

2) How does the cooperative education model work in bridging the gap between theory and practice in engineering education, meeting the new developments of industrial needs?

The results have both academic and practical value in deepening the experiential learning, work-integrated learning and student-centered curriculum reform in Chinese engineering undergraduate programs.

2. METHODOLOGY

A. *Case Study Method*

To answer the "What" and "How" questions, one-case study method was used, because case study is best suited to answer descriptive and explanatory questions. Furthermore, cooperative education has different models in different universities, and case study can best embody the characteristics of the model.

B. *Case Unit Selection*

The analysis unit of this case study is the cooperative education program of biomedical engineering undergraduates. We choose Southeast University (SEU) and Beijing Genomics Institute (BGI) Company at Shenzhen as the case unit since the two units have signed a joint agreement to educate excellent engineers. SEU has a good reputation in engineering education for 110 years and maintains innovation in cooperative education to establish academic learning and work experiences from enterprises. BIG is one of the leading enterprises of gene research and application industry, aiming to develop research collaboration and provide scientific support to scientists all over the world, contributing to the advancement of innovative biology research, molecular breeding, healthcare and related fields.

C. *Conceptual Framework*

Conceptual framework is the base of logical linking data to proposition and the information navigation for material collection and analysis. In this paper, we address the following conceptual framework around research questions with the reference to the criteria for accreditation for cooperative education of NCCE [7] and CAFCE [8], as seen in Figure 1.

What is co-op	→	**How co-op works**
1. Mission and Goals of the Program 2. Institutional and Structural Commitment 3. Expected Learning Outcomes 4. Curriculum Plan 5. Activities to Guide Learning 6. Monitoring and Assessment 7. Learning Workplace and Environment 8. Learning Effectiveness		1. Basic Attributes 2. Main Principles 3. Essential Characteristics 4. Core Components of Best Practice 5. Benefits and Educational Value 6. Problems and Key Issues

Figure 1. Conceptual framework for case study

D. *Data Resources and Materials Collection*

Three principles were established to collect data and materials: using multiple sources of evidence, establishing case study database and forming a series of chain of evidence. The six sources of materials are: documents, records, interviews, direct observation, participant observation and physical evidence.

Total numbers of 20 participants were interviewed in this study, which was conducted from May to August in 2012. The interviewees cover different stakeholders of engineering education including senior and junior students, graduates, faculties, technical experts and engineers, employers and administrative staff of both SEU and BGI.

E. *Avidence Analysis and Results Presenting*

The case materials were classification after collecting according to the conceptual framework, thus forming database and chain of evidence. We use pattern matching techniques to analysis the data and finally present the results in descriptive and explanatory words and form. Answers of interviewee were coded. For example, "Q-10" where the number 10 represents the order number of the participants.

3. RESULTS

This section details the specific results of what is the cooperative education model in SEU according to the elements of conceptual framework.

A. *Mission and Goals of the Program*

Mission and goals are used to guide the program's practices and policies and to evaluate effectiveness.

Mission Statements: This program is aiming at educating excellent engineers among the biomedical field in the undergraduate level. Cooperative Education is adopted and implemented to educate students in both the theory of their academic profession and the practice of today's engineering marketplace. The mission will be accomplished through student, faculty and employer involvement to maximize the students' active learning.

Goals Statements: Graduates from biomedical engineering major of SEU are expected to have: 1) basic knowledge of relevant sciences, technology and engineering; 2) the core engineering professional skills and ability of technology application, medical equipment innovation, market analysis and product selection; 3) personal ability and attitudes; 4) effective

communication and leadership in multi-disciplinary team within the background of globalization.

B. Institutional and Structural Commitment

SEU has a long-tem strategic plan for implementing cooperative education and newly formed a special organization named Cooperative Education Office under the administration of Academic Affairs Department of SEU. Also, SEU has effectively included cooperative education as integral part of the academic program and has implemented policies and practices appropriate to the achievement of program mission and goals. The program for biomedical engineering has been proved by the Committee of Curriculum and Teaching of SEU.

1) Time alternation and credits awarding

The 4 year academic time of our new program is divided into 2 parts: 2.5 year campus-based classroom study and 1.5 year company-based work experience with multiple small periods. Time spent in the work portion of the curriculum encompass nearly 40% among the total time. Students alternate work and study in full-time to encourage maximum focus on the workplace or on academic study. During the 2.5 work time, students start and end with an academic study term to ensure the preparation for work term and the synthesis of the work experience into the total program. All the courses in co-op workplace are awarded 30 credits of the total 150 credits of the entire program.

2) Students' number and eligibility for participation

Up to now, 20 students from biomedical engineering major in SEU were selected to join the innovative program in the last 3 years. Co-op students start their work-based study in BGI in March from the year of 2010 to 2012. Among the 20 participants, the distribution of each year is: 9 in 2010, 6 in 2011 and 5 in 2012. There are 2 graduates was employed formally, 3 graduates pursue their graduates study in BGI and 10 graduates choose to departure for other employer.

Co-op employment occurs through competition. The selecting procedures are: student application, written and oral examination and interview. At the end of each year, interviewer form BGI come to SEU to select students occurring through competition ratio of 20%. The basic conditions for co-op participants are: problem-solving ability, potential of biomedical research and application, communication, team work ability, good interpersonal skills and engineering leadership.

3) Budget and resources guarantee

The cooperative program has financial budget each year acknowledging both the fixed and variable costs of operating a co-op program. The program has received special financial support of 2 billion RMB as the starting capital, and will get other items of found form the Chinese government. Meanwhile, the university and BGI will definitely input money including the course fee for teachers both in SEU and BGI. The co-op students receives remuneration for the work performed.

4) Cooperative agreement and management system

Cooperation agreement with SEU and BGI provides evidence that the co-op education program is not merely a "politically expedient and attractive option" for SEU, but a education innovation program for educating the future qualified engineers in biomedical fields. SEU and BGI have jointly made out the following agreements: SEU-BGI joint agreement for educating engineers, the 4 years program plan, the 2.5 years work-based study plan in BGI.

Also, there are student administration regulations, requirements for capstone courses in BGI and the regulations for teaching, learning, quality evaluation, faculty qualification in BGI. Besides, SEU has developed measurement of the satisfaction of students, employers, faculty and staff through surveys, as a regular component of the program enables responsiveness to internal and external changes.

C. Expected Learning Outcomes

Cooperative education provides students with the opportunity to develop those skills which industry has identified as critical for success. Thus, it is vital to set learning outcomes that is what students have learned after the co-op work-based study. SEU and BGI have formed in common the learning outcomes with both technical "hard" skills and non-technical "soft" skills.

The 4 indicators of first level of learning outcomes are: 1) technical knowledge and scientific thinking and autonomous learning ability; 2) analysis and problem solving ability; 3) communication skills; 4) personal and professional ethics and social responsibility; 5) participate, lead and management a project. Accordingly, there are more specific indicators in second and third level of learning outcomes, thus forming a entire syllabus of co-op model.

D. Curriculum Plan

SEU-BGI curriculum system is divided into two parts: theoretical courses and practical courses, the structure and contents are shown in Table 1.

TABLE 1 CURRICULUM PLAN STRUCTURE

Category	Type	Credits	Number	Term
Theoretical courses	biomedical frontiers	4	2 courses	3-3
	discipline basics	16	8 courses	3-3 4-2
	professional literature and writing	4	2 courses	4-2
Practical courses	primary	2	7 experiments 3 lectures	3-3
	intermediate	4	2 projects	4-2
	advanced	10	2 projects 1 capstone	4-3

In table 1, problem-based learning is mainly used for theoretical courses and project-based learning for practical courses. All of projects were awarded credits if only the students complete the research paper and pass the debating oral examination and product demonstration. For example, Hou Yong, senior of 2010, who has accomplished 3 advanced projects and employed in BGI now. His advanced projects are as seen in table 2.

TABLE 2 HOU YONG'S ADVANCED PROJECTS

Time	Project Name	Role & Task	Expected Results
2010.5-2011.12	Applying Optical Mapping to Genome Assembly Research	Participant, 2 sub-project research	Academic paper
2010.7-2011.1	Five Kinds of Cancer Research Based on Single Cell DNA Sequencing	Sub-project charger, information analysis	Patent application, Academic paper
2011.3-2012.6	Research on Rare Cell Separation Technology based on Micro-fluidic	Project manager	Patent application, Academic paper

E. Activities to Guide Student Learning

Well designed activities will enhance student learning and offer concrete evidence of learning to the university and to the employer. All the activities are taken seriously by student, the supervisor and the co-op educator in BGI, because many different outcomes can be found if the activities are used well. There are 6 kinds of activities which helped and facilitate the process of the co-op study.

1) Theme discussion in technology groups

In BGI, the research employments are divided into several big groups named "Technology Group" according the technology branches. Meanwhile, each technology group consists of small groups named "Research Group" based on the research project. Specific themes from frontier technology are discussed every month in round table room, with the contents of new development of applied science, technology application and engineering innovation.

2) Series of seminar in research goups

In each research group, the project manager calls seminars every 1-2 weeks. A series of topics were well-designed before the seminar. The contents of this kind of seminar focus on the research process, technological and method breakthrough and engineering design.

3) Experts lectures

Co-op students attend about 40 lectures in BGI within the scope of gene science, medical science, computer science and analysis approach, etc.

4) International academica and research conferences

Attending import research conference with academic paper is a innovative way to study through research for students in BGI. Totally, SEU co-ops have attend 5 high level conferences international. They communicate stage research results with experts and scholars in this field through presentation in the conference.

5) Small training class and open forum

Co-op students host small training classes in summer and Autumn to introduce special topic related to research project. Open Forum is hosted in summer talking about work-related experience among co-ops from different universities.

6) Recreational activities based on enterprise culture

Recreational activities are available during the work-term in spare time such as jogging, climbing, dancing, picnic and party and so on. By these activities, co-ops have the opportunity to communicate deeply with the former employees and employers in BGI.

F. Monitoring and Assessment

SEU and BGI have their own monitors responsible for the work-integrated study. In BGI, two kinds of supervisor are assigned formally for each student: leading supervisor who provides the science frontiers, concept and thinking and research supervisor who guide the cooperative students in specific projects. They provide a real world perspective and timely real word situation for students.

All the supervisors are the elite of the technical force of BGI and charges for the performance evaluations and work assessment altogether with the SEU tutors. Evaluations remain part of the student's cooperative education file. The hallmarks of assessment are multiple: data collection, personal respect, peer review, project-based assessment and portfolios.

G. Learning Workplace and Evironment

BGI provides the suitable learning situation of workplace and research environment including world-advanced laboratory and equipment of gene and bio-medical research and practice for co-ops. In March 2012, BGI at Shenzhen was awarded "SEU-BGI National Engineering Practice Education Center", located in BGI at Shenzhen, providing real work site for the co-op studies. The Center is administrated by SEU and BGI in common, with the main task of making out joint practical learning objectives, process and assessment. The Center received 2 billion RMB from the government as the starting capital and established Teaching and Learning Committee, Administrative Committee.

H. Learning Effectiveness

The program has developed and implemented for 3 years, demonstrating effectiveness of co-op model learning in BGI. From the student's perspective, there are 4 kinds of results providing evidence for the learning effectiveness.

1) Academic paper

High level papers were published to support the learning effectiveness. Represented by Hou Yong, Chen Peisheng and Yuan Yanting, 5 academic papers were published in Cell, PloS One, Journal of Bacteriology, Journal of Maternal-Fetal and Neonatal Medicine, with 2 papers of above 30 impact factor are the fist authors of co-op student.

2) Invention patent and software copyright

Co-op students have been the participants of 13 invention patents, and Hou Yon has 2 patents with the role of co-holder. Besides, Li Yiyuan gained 1 software copyright as the co-author.

3) Professional and occupational development

Cooperative education experience has a very positive effect on their careers. At the end of 1.5 year work session, many students have been the core members of the research team, and 2 students been the backbone of technological group. As Hou Yong and Chen Peisheng are the formal employees after graduation, the former is now the manager of sub-technical group who leads the

13 people team and responsible for 12 projects, the latter is now another manager of sub-technical group.

4) Improved skills, abilities and attitude

Co-op students benefit from the work-integrated experience with improved personal and professional skills and attitude, both technical and non-technical. SEU' students with BGI experiences have a significant and positive effect with regard to learning effectiveness and self-recognition. We interviewed some of the co-ops, for example:

"In BGI, I supplement knowledge and its application according to my own work, so learning in BGI is highly efficient". "Sometimes, it is more important for wok that is ways of thinking, skills of communication and expression". "Learning experiences in BGI plays a vital role in developing my ability of thinking, learning and communicating". "Working in BGI enables me how to conduct research and lead a team something like leadership".

4. DISCUSSION

This section discusses the rational and potential factors of why and how the cooperative education model in SEU&BGI effectively works based on the above results and conceptual framework.

A. Attributes: Student,Faculty and Employer Involvement

Involvement of student, faculty and employer is the basic attributes of cooperative education. Within SEU-BGI program, students actively involve in the courses, academic and research activities covering almost learning process in BGI with the practical knowledge and skills obtained. Faculties from Biomedical School of SEU involve the program as lectures, tutors and administrators. Employer involves the program as the role of interviewer, tutor, supervisor and guider. The co-involvement of different main body of the cooperative program strongly supports the success.

B. Principles: Full Range of Deep Joint with SEU and BGI

At the beginning of the new program in 2010, SEU set 5 joint principles with BGI around the entire process of educating and learning. Principles are: jointly set the learning outcomes, construct curriculum, conduct teaching, manage the educating process and assess and evaluate the learning effectiveness and program quality. The results of this study embodied above principles, especially the co-op student's performance and achievements on the job are monitored and evaluated by SEU and BGI in common.

C. Characteristics: Work-integrated, Research-oriented and Academic-related

From the analysis of the results of what is the SEU-BGI cooperative education model, we can see 3 essential characteristics which differ from the regular program of SEU. First, the co-op students are engaged in productive, authentic and full-time paid work rather than merely observing. Second, learning process is oriented by research with the problem-based, project-based and learning by doing approach. The BGI co-ops have effectively achieved high level papers and patents. Third, work terms involve both theoretical and practical course and activities related to the student's academic or career objectives instead of isolating the work-based study from the academic goals.

D. Components: Three Stages and Six Pillars of Practice

As you ask why the SEU-BGI model works effectively, core components of the practice in BGI is another factor contributing to the successful learning. The components are classed into 3 stages: co-op preparation stage for warming up, during the Co-op term for learning and post co-op stage for reflection and evaluation. We sum up these components as shown in figure 2.

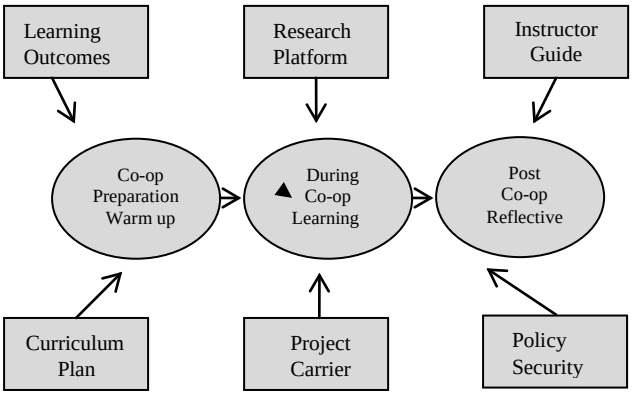

Figure 2. Three stages and six pillars of best practice of SEU-BGI

E. Multiple Benefits and Pedagogical Educational Value

Cooperative education is so powerful because its outcomes serve both educators and employers and all to the benefit of students. Just as one interviewee students said "It is a valuable experience in BGI, co-op learning makes me not only develop my technical skills, but also provide me the transition from the role of student to professional in the industry". BGI also benefit from the education. "Co-op students are an ideal source of manpower to fill temporary human resource and reduce future recruiting costs for BGI", one manager said.

After all, cooperative education is an academic program for engineering therefore its educational value is comprehensive. From the case of SEU-BGI model, we can find the following potential pedagogical values. First, co-op education is not merely a learning experience but experiential learning in real-world work site with reflective assignments. Second, co-op education is student-centered, self-directed learning monitored and evaluated by both institution and enterprise. Third, co-op education is a collaborative learning with peers, faculty, tutors, coordinators and work site partners. Fourth, co-op education is problem and project-based learning (PBL). As demonstrated by the case of BGI, the instructional method of theoretical courses is problem-based where relevant practical problems are introduced to motivate the learning, while practical courses is project-based and multiple levels and contents.

F. Problems and Key Issues

The problems still exist. BGI hopes that more senior students join the program with the expanding scope of computer and medicine engineering major and that young teachers of SEU join the program with the role of supervisor and BGI can provide practical training for them. While SEU considered how to join the program in the level of graduate students and engage in series courses in the direction of medical electronics. The key issues also include student security during work term, technology secret for BGI, attribution of intellectual property made by co-op students in work sites and the real value of undergraduates of SEU for BGI.

5. CONCLUSION

The role of cooperative education in engineering education has a long history and needs to be investigated in the context of different educational goals of different institution. Co-op students have the opportunity to understand the curriculum well and know how to apply classroom knowledge into workplace practice. It seems to be an important and effective learning opportunity for engineering education in China under the context of "National Excellent Engineers Education Program". However, cooperative learning experiences should be seriously designed, delivered, evaluated, reflected and improved.

In this case study, we address the "What" and "How" research questions of cooperative education model, propose conceptual framework for materials collection and analysis. The results cover several aspects of the cooperative education model in SEU and BGI of China. Finally, we discussed the attributes, principles, characteristics, components and the pedagogical value of the SEU-BGI co-op model, in order to reveal the factors contributing how the model works effectively.

Although the results vary in strength, this study has found the main features of the co-op model, especially the principles, characteristics and the components. These findings may be valuable to others universities who are expecting to deliver a cooperative education. Other findings also enlighten the best practice of cooperative education in developing countries.

It is worth mentioning that, this research work only examined one case in China. Thus, the research findings and conclusions have limitations. Follow-up to this study will be done to draw more general conclusions by comparing more cases and revealing regional and institutional differences.

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