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Outcome-Based Teaching and Learning in Computer Science Education at Sub-degree Level

Gary K. W. Wong, *Student Member, IEEE, Member, ACM* and H. Y. Cheung

***Abstract*—Computer Science is recognized as a young growing field compared with many other sub-degree and even undergraduate programs. Recently, many educators in this field teaching in community college as well as university have been recommended to redesign and restructure the program studies according to outcome-based teaching and learning approach. However, the issues related to how to define objectives and assess outcomes in this outcome-based approach (OBA) continues to be a challenge among the computer science faculty who are not originally trained in techniques for setting up objectives and measuring outcomes. This paper serves as a brief introduction of OBA and how it can be implemented from the program design perspective. In this paper, our experience of initial attempt in designing and developing our sub-degree computing program using OBA will be shared. In addition, the writing style of course learning outcomes and outcomes measurements are illustrated through example of two courses. Based on the OBA paradigm, we evaluate our teaching effectiveness and student outcomes based on the teaching evaluation results and their articulation success. Through deeper understanding and learning, outcome-based education can eventually bring a great impact on students and prepare them for both exciting career and successful articulation in the computing field.**

***Index Terms*—Outcome-based teaching and learning, teaching evaluation, community college teaching, computing curriculum, post-secondary education**

I. Introduction

Outcomes-based education recently has become a major focus in teaching and learning enhancement for many fields of studies. Over the past few years, University Grants Committee (UGC) in Hong Kong has stressed the importance of emerging the outcome-based framework in both design of curriculums and teaching pedagogy. Yet, the concept of outcome-based approach (OBA) teaching and learning can be traced back to an early stage of education evolution [1]. Despite the long history of this OBA framework, outcome-based computer science education seems to be a new concept in our teaching and learning approach.

In a traditional teaching of the computer science subject, both theoretical and practical contents are driven by the new innovative technology in industries. A course about computer programming is all about teaching students what a computer language, for example C++ or JAVA, can do and perform. It is rarely to have a tight relationship with what a student is expected to achieve at the end of the course. A question is, should we simply teach all the related topics to students so that they know how to create an array with pointers? or should we expect the students to be able to create a point of sales (POS) system which multiple commands? Perhaps a student can complete this course with high grade because of simply knowing the meaning of a command, but not knowing how to manage of using some groups of commands to formulate a working computer program to solve a financial calculation. Unless the outcome is presented clearly and precisely to the students, the whole course can become useless and is a waste of time. Similar to other courses in other fields of studies, what is taught plays no meaning if a certain ability of students is not expected at the beginning of a course. That is the reason that the ”Outcome-based approach” is brought forth and introduced to every educator, particularly in the field of computer science.

At our community college, students usually come from with different academic backgrounds. Even the enrolled students in our computing program studies, no prerequisite requirement is expected from them. In other words, students who are interested in majoring in computer science at the sub-degree level should be trained and taught from the foundation and basic so as to prepare them for higher education. In addition, our sub-degree program studies targets on industrial oriented approach which is also suitable for students who desire to articulate to a computer science degree program. Given this specific articulation path as the outcomes of the program studies, the method of teaching and learning including learning activities and assessments needs to have a clear objectives both for teachers and students. In order to guarantee that students achieve certain outcomes, the curriculum design needs to be as specific as possible so that the expectation can be easily reached. The implementation and evaluation of a computer science program as sub-degree level are not widely studied. Our contribution to this outcome-based approach in teaching this area should be among the pioneers. Through the evaluation of this framework, it can motivate others to realize the usefulness and effectiveness in their curriculum design using OBA. With this approach, it could become easier to reach out to other fields and lead to a better development of interdisciplinary courses in computer science.

The paper is organized as follows. In section II, a highlight of ongoing activities is presented related to the OBA research and discussion among the computer science task forces, and some of the challenging issues in realizing the OBA teaching and learning. In section III, an overview of the OBA framework leads to a sample of our newly developed

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Gary K. W. Wong is with the Community College at Lingnan University, Tuen Mun, Hong Kong, China, (e-mail: garywong@ln.edu.hk).

H. Y. Cheung is with the Community College at Lingnan University, Tuen Mun, Hong Kong, China, (e-mail: h3cheung@ln.edu.hk).

curriculum Higher Diploma program in Computer Studies. Through this curriculum design example, we illustrate how an outcome based curriculum should be designed and developed in terms of program learning outcomes and assessment activities design. In Section IV, the design of learning outcomes and outcome measurements will be provided with examples. In section V, we will provide a teaching evaluation of two courses in this program to serve as insights from the perspective of students on the OBA teaching and learning. This paper will be concluded in section VI. We believe our motivation and OBE design principles can be applicable and make a good contribution to other fields of studies.

II. Motivations and Related Works

In computer science or general studies of computing, this term OBA did not exist in any literature until recently. Simply speaking, OBA is a teaching and learning methodology which focuses on what students are expected to learn and how it becomes measurable through assessment. In many academic journals and articles, some other terms may be familiar such as outcome-based education (OBE), outcome-based teaching and learning (OBTL), and outcome-based learning (OBL). Indeed, this term was quite popular in the United States during the 1980s and the early 1990s. At that time, some other terms were adopted, for instance, mastery education and performance-based education. No matter what the term is used, the structures and the elements are more or less the same.

Again, two major tasks are the key components in this OBE framework. The first task focuses on explicit statements of what students will be expected to be able to do after taking the course or completing the program study. This section is usually referred to as "Learning Outcomes". In curriculum design of a program, a set of learning outcomes are required to be mapped to all the courses under the program. It is an important part because all the courses together should fulfill every outcome set in the curriculum. However, how to manage the outcomes in each course and ensure their fulfillment to the program outcome can create a burden for the department. In [2], the author illustrates how to connect objectives and outcomes using the resources from CITIDEL (the Computing and Information Technology Interactive Digital Education Library) to improve course preparation. Further example in taking the advantage of information technology in managing outcomes of curriculum across related degree programs can be referred to [3]. After learning how to manage learning outcomes, it is normal to consider how the outcomes of a computer science program should be designed. In [4], the authors conducted a series of structured interview with IT employers and seek for their perspective on needs skills and knowledge for a career in IT. Knowledge, skills, and competencies that the employers particularly value when hiring IT graduates. After it is known of what the curriculum expects, the next task is to focus on the writing style of the learning outcomes. Bloom's taxonomy of the cognitive domain and the SOLO taxonomy are two most popular frameworks widely used in the design and assessment of courses. Yet, this classification system is found not suitable in computer science because of the different contexts compared with other fields. The work in [7] provides details of analysis and a new taxonomy for computer science and also engineering is proposed. Some research works on OBTL are also found targeting on the web-based learning other than traditional classroom learning. References can be found in [5] and [6] for further study. Nevertheless, we can see the trend of OBA applied in teaching and learning, specifically in computer science curriculum.

Once the expectation is promoted and clarified, the next crucial task is to state how these students will learn it, or simply the teaching and learning activities, which leads to the assessment procedures and rubrics. Sometimes in literatures it is called "Outcome-based Assessment" [14]. Most of the OBE frameworks follow the same patterns in terms of stating learning outcomes, teaching and learning activities, and outcome-based assessments. Similar to managing learning outcomes, assessment activities can also be effectively managed using technology to facilitate the learning and assessment process [8]. In 2007, one panel and poster were organized to discuss the assessment issues related to outcome-based learning [11], [18]. Indeed, the assessment using OBA can actually offer some meaningful and useful feedbacks to the teachers regarding student achievement, assessment, and the quality of the instruction [14]. Many people may think that the organization of the assessment data using OBA can take longer time than usual. But the authors in [14] claim that the time required to perform the analysis was minimal. Initial setup only took an hour or two to create the tool to automate this process. Thus, it is worthwhile to experiment further on this approach. Some other related works on the assessments can be related to [12] and [13] to gain more insights on the design of assessment activities.

To trace back the numbers of public discussions of outcome-based computer science education, it leads to several conference panel held in the United States [15], [16], [17], [18]. These panel discussions were basically provided a platform for educators and researchers to understand from each other on their perspectives related to how OBE becomes practical, mainly for computer science education faculty. From these panels, few articles were published as references. One recent example can be referred to [19] when they studied the effectiveness of OBA in teaching computer science courses. They obtained their results through the feedbacks from both university instructors and students in Hong Kong under the OBA learning pedagogy. Surprisingly, the results found that most of the instructors eventually switched back to time-saving norm-referenced assessment. Students were also found to perform similarly compared with our traditional learning methods. No doubt, most of the teachers in teaching computer science are not originally trained to adopt this OBA framework like many other departments do. The goodness and effectiveness of this method may not be manifested at this moment due to the lack of understanding and acceptance to the pedagogy. Despite of the immaturity of OBA framework, a promising future is shortly to be realized. I personally believe that it is a true education all about when we turn teaching to a student centric approach.

Other related studies over the general idea of OBA and

the case study of OBA in their disciplines can be referred to [20]. Particularly, groups of scholars have conducted a research study on the transference of learning approach among students when OBTL is implemented. This is an interesting effect and phenomenon to see how students adopt to the OBTL in their learning tendency [21].

III. Outcome-based Approach Curriculum

A. Overview of OBA Framework

OBA is an approach applicable in program and course design. Teaching and learning under this framework focuses on the expectation of students after their completion of the program studies, what they are expected to learn and perform, rather than what the teacher expects to teach and present. Once the objective is shifted to the student-oriented approach, the quality skills of graduates are expected to be further enhanced. Note to mention that under the OBA framework, the rubrics in assessment normally leads to a criteria-referenced assessment (CRA) rather than the traditional norm-referenced assessment (NRA) [22]. The advantage of CRA focuses on the expectation of student's learning, skills they should have in order to obtain a higher grade. That way, accreditation can be based on the learning outcomes of graduates to determine if the program can achieve to certain training purposes. However, some limitations and unsuccessful implementations have been seen in academics [23]. Whether it is true for the computer science education in post-secondary level is yet to be investigated.

In our community college, we have attempted to design our first intake of Higher Diploma (HD) in Computer Studies based on the OBA framework. After three years of training, we have recently produced our first group of graduates in 2010. The quantitative analysis have shown that these students seem to have done it well for the articulation both in career and education, where near 30% of them were successfully articulated to local university degree programs, and the others were able to seek for full-time jobs in Hong Kong. In addition, another group of students from Year 1 HD in Computer Studies (PC System and Networking) began their studies in 2009. Around 80% of them have been successfully articulated to the Year 2 program. They seem to continue to find success under the OBA teaching and learning environment. We expect this group of students to graduate in 2012. Before looking at the course evaluation done by these students, an example of the program curriculum design is briefly shared to demonstrate how a program should be designed and developed to focus more on the students.

B. Example of OBA Curriculum Design

HD in Computer Studies is originally designed as a job oriented approach so that students are expected to learn skills which are essential to their future jobs. For example, suppose a student wants to become a computer programmer, he/she should be able to write programs using different languages such as C++ or JAVA upon the completion of the program studies. At the beginning of the program specification, we should clearly state that the learning outcomes and objectives of this program. Here we provide an example for reference.

1) Concentration Objectives: In our Higher Diploma in Computer Studies program, it is designed to meet the following aims:

- to develop students' ability in designing, developing, and supporting software and computer network, so that they can contribute towards the advancement of information technology and computer technology in both the public and private sectors;
- to provide basic knowledge in computer science which allows graduates to grow with and adapt to new technological developments in a practical environment of software design or system development;
- to provide basic knowledge in technical, economic, management and legal disciplines relevant to computing and the IT industry;
- and to increase students' ability and confidence for independent thought and creativity.

2) Curricular Objectives: The curricular objectives of the program are:

- to provide students with the knowledge and techniques to effectively design and manage small-scale computer system development projects, and to be able to develop a career in a related industry;
- to provide students with professional training so that they may possess the ability to adapt to different but related working environments in computing and the IT industry;
- to equip students with the fundamental knowledge for further technical and career development, and a qualification to enable them to proceed their studies leading to degree qualifications, locally or abroad;
- to promote students' ability in communication, and awareness in social and moral responsibilities, especially being computing and IT professionals; and
- to be aware of the significance of business and management issues, as well as participation in developing business systems.

In addition, there are more specific objectives that are pertinent to this program, a graduate will:

- demonstrate knowledge in IT technology management, and apply up-to-date management methods in the related industry;
- acquire knowledge and skills in computer programming, computer network installation, operation and management; and
- possess sufficient knowledge for progression to undergraduate degree programs offered by local or overseas universities.

3) Course Components: After that section in the document, we have clearly stated our program components, such as courses needed to be taken and their major contents descriptions. More importantly, teaching and learning methodology is included in the document.

Elementary data structures, introduction to systems analysis and design, information systems management as well as discrete mathematics and statistics are taught in the first year. A formal introduction of all the key building blocks, will also take place in year 1, with the emphasis partly beginning

to shift from the fundamental programming techniques to a more professional perspective and industry standard tools. The programme develops more intensive programming skills (in C/C++) alongside crucial concepts like data structures and programming methods. Structured systems development methods are also introduced. Software project management is taught in order to introduce students to the software development life cycle. Students are also trained to document the design and coding for software systems.

Further programming and software development concepts and techniques together with more advanced or contemporary units are studied in the final year. At the end of the year, students are able to operate and connect a PC network, and have acquired the basic software techniques for developing network and database systems that would be extended to manage information systems. Advanced subjects, such as knowledge-based systems, object-oriented analysis and design and human computer interface are intended to strengthen students in logic programming techniques. Prior to graduation, projects are assigned to students to gauge the overall culmination of knowledge, understanding, techniques and skills that they have acquired in the programme of the two years of study. They will be able to analyze, design, implement, test, document and present a software project commensurate with their level of competence.

4) Teaching and Learning Activities: In our HD program, we emphasize that lectures, tutorials, seminars, case studies, guest talks, and projects are provided to students so that they have opportunities to learn from real examples and then practice on their own in writing codes and formulate working computer programs similar to the examples. In addition, problem-solving skills are developed through applying a range of techniques and ideas in handling business problems. Students are encouraged to think independently, and to apply appropriate control measures in accomplishing specific tasks. The teaching and learning methods enumerated above will create a learning environment in which the students play an active role. To achieve this, students will be encouraged to adopt an active knowledge-seeking attitude and to build up confidence in their own ability to communicate and work with others. Since designing the program needs not to divide it out all the sub-learning outcomes, the statements above should be sufficient to clarify the directions of this program.

During the scheduled teaching hours, a variety of teaching methods will be used to disseminate, analyze and develop subject matter within the programme curriculum. Teaching is normally carried out in the form of lectures. The lecture materials on the subjects are presented using a 'more teaching than lecturing' approach, i.e. lectures are not one-sided: both students and lecturers are encouraged to participate interactively. It is strongly supported by the use of worked examples (within the confines of lecture time and tutorial time). Class assignments are frequently used for reinforcing the materials given in the lectures.

Depending upon the nature of the subjects, all or some of the followings will be employed:

Lectures: A lecture will comprise a discourse or presentation of arguments in which the lecturer introduces new material or expounds on material already presented. Students will be encouraged to raise questions on the subject matter and to participate in short structured discussions. Lectures may be complemented by seminars to provide the opportunity for student discourse and discussion at the appropriate level. The aims of lectures are to: Introduce and explain concepts; demonstrate how to illustrate and analyze an issue; and Indicate a pattern of further study in order to attain a suitable depth of knowledge in the subject area.

Tutorials: During tutorial periods, students will be encouraged to initiate discussions of the subject matter related to the teaching materials. Aims of the tutorials are to: Enable students to develop a range of concepts and skills appropriate to the needs of business; Develop students' abilities to think independently in order to understand the methodology of a discipline; and develop insights by exchanging ideas and clarifying misconceptions with classmates and the lecturer.

Seminars: The instructor provides background information of an issue for guiding discussion with students in class.

Case Studies: The application of cases analysis enable students to examine, analyze and solve problems of a real and practical nature in the industry.

Guest Talks: Experienced practitioners and experts may be invited to deliver speeches to students in order to share up-to-date professional knowledge with the students.

Projects/Team works/Exercises: Students may take part in projects (or team works or exercises) to apply and integrate the knowledge they have learned from class. Students will learn that careful preparation is necessary to have satisfactory results. Moreover, presentation will be required to ensure that the specified objectives have been met. Problem-solving skills are developed through applying a range of techniques and ideas in handling business problems. Students are encouraged to think independently, and to apply appropriate control measures in accomplishing specific tasks.

The teaching/learning methods enumerated above will create a learning environment in which the students play an active role. To achieve this, students will be encouraged to adopt an active knowledge-seeking attitude and to build up confidence in their own ability to communicate and work with others.

C. Program and Courses Outcomes System

On the program level, the OBA framework suggests that all the course learning outcomes should point to the ultimate objective outcomes in the program studies. Indeed, we have attempted to do it in this fashion. However, one of the difficulties we may be facing is whether each of these program learning outcomes can be met by all the courses provided in this HD program. At this moment, this remains a good question to be investigated. However, our initial idea is to take the advantage of a system application software called *Program and Courses Outcomes System (PACOS)* [24] developed by a group of research students at the Hong Kong University of Science and Technology (HKUST). Program and Courses Outcomes System (PACOS) is a free, open source web-based system. It was designed to be used by a department of a university or similar institution as a centralized web system

for the members of the department to access and amend the course-outcome mappings of programs offered by the department. We have already installed and implemented the system software. Our future direction is to merge our HD in Computer Studies program into this system and test if our courses can fulfill all the learning outcomes at the program level. If not, we can modify the course learning outcomes and assessments accordingly.

IV. Learning Outcomes and Measurements

According to [25], it offers an excellent commentary and insights on what effective learning outcomes are. To recall, our objective in OBA teaching and learning is to shift our paradigm from teacher-centered approach to student-centered approach. That means, learning outcome statements are to reflect and express what students are expected to be able to do at the end of the learning periods. For references, we include three statements of definitions:

"*Learning outcomes are statements that specify what learners will know or be able to do as a result of a learning activity. Outcomes are usually expressed as knowledge, skills or attitudes.*" [26]

"*Learning outcomes describe what students are able to demonstrate in terms of knowledge, skills and attitudes upon completion of a programme.*" [27]

"*A learning outcome is a written statement of what the successful student/learner is expected to be able to do at the end of the module/course unit or qualification.*" [28]

The practical technique of writing effective learning outcomes mainly depends on the correctness of verbs used in the statements. In [25], it mentions that Bloom's taxonomy is commonly used for writing learning outcomes give the benefits of its ready-made structure and list of verbs. All of these verbs are measurable, meaning an appropriate assessment activity can effectively measure whether a student has achieved the learning outcome. For example, one of the learning outcomes in a course can be, "Upon the completion of this course, students will be able to develop a small knowledge-based system using a rule-based shell." A good assessment activity can be to a group project-based approach. If a group of students can work together to develop such system, then we can confirm that the students have achieved the learning outcomes. Furthermore, peer and instructor evaluations can confirm if each of the students have made an appropriate contribution on the project.

A poor example of learning outcomes can be, "Upon the completion of this course, students will be able to understand how to use a rule-based shell to develop a small knowledge-based system." In such case, whether a student understands or not is difficult to measure. In other words, the understanding of a knowledge cannot be reflected by any mean as a student can simply respond with a feedback that he/she understands totally. At the end, he/she may still be not able to develop a working system. To omit such ambiguity, appropriate action words should be chosen while writing learning outcomes. [29] offers a practical advice for writing learning outcomes, which can be referred to the Table I. Due to the scope of this paper, further reading to enhance the understanding about how to write learning outcomes and measurements can be referred to [25].

TABLE I
ISMH13 Knowledge-Based Systems

Aims	Outcomes
Know	Distinguish between
Understand	Choose
Determine	Assemble
Appreciate	Adjust
Grasp	Identify
Become familiar	Solve, apply, list

V. Evaluation of Teaching Performance

To demonstrate the effectiveness of this OBA teaching and learning pedagogy, two sub-degree courses in the HD program were studied and evaluated by students. The results are presented to prove the success of our first cohort in this HD in Computer Studies program at our community college. These two courses are ISMH13 Knowledge-Based Systems and ISMH15 Computer Ethics.

In Table II and III, Score 6 is the highest value while Score 0 is the lowest value. It is clearly that the outcome-based course structure provides the effectiveness of the teaching and learning. It creates a better organization where all the activities can reflect the usefulness of the skills they learned. Assessment becomes more clearly explained because students expect what they need to learn and do upon the completion of the course. Students overall feel their progress in developing intellectual skills through the course as the outcomes and objectives are clearly stated in the course syllabus as well.

Due to the limitation of pages, two other courses ISMH09 Management Information Systems and ISMH10 Human Computer Interfaces were studied, but not yet to be included in this paper. However, we observe a similarity among these courses in the evaluation results. This offers an intuition that the outcome-based approach framework can enhance teaching and learning in overall performance among the program study.

VI. Conclusion

In conclusion, it has been widely promoted with evidences that OBA is indeed a promising direction in our education system such that student outcomes are to become a driving force and motivation of teaching and learning. As many places especially Hong Kong are going through a new era of educational revolution, perhaps OBA framework is the antidote to bring the revolution to the highest success ever. No single pedagogy is yet perfect, but educators should continue to make effort to enhance the teaching and learning process. After we realize the goodness of OBA framework in our sub-degree sectors, we believe that our students will continue to be trained and become potential future leaders in our society. In the future, we will continue to conduct both qualitative and

TABLE II
ISMH13 KNOWLEDGE-BASED SYSTEMS

Question	Score 0-3	Score 4-5	Score6
Organization of Course	0%	100%	0%
Reasonable Workload	0%	75%	25%
Usefulness of Course	0%	80%	20%
Various course components integrated	0%	80%	20%
Usefulness of Feedbacks	0%	80%	20%
Clarity of course objectives	0%	40%	60%
Course learning outcomes achieved through activities	0%	80%	20%
Assessment effectiveness	0%	80%	20%
Clarity in assessment explanation	0%	80%	20%
Development intellectual skills through the course	0%	80%	20%
Course contribution to overall learning experience	0%	100%	0%

TABLE III
ISMH15 COMPUTER ETHICS

Question	Score 0-3	Score 4-5	Score6
Organization of Course	0%	80%	20%
Reasonable Workload	0%	60%	40%
Usefulness of Course	0%	60%	40%
Various course components integrated	0%	80%	20%
Clarity of course objectives	0%	80%	20%
Usefulness of Feedbacks	0%	80%	20%
Course learning outcomes achieved through activities	0%	100%	0%
Assessment effectiveness	0%	80%	20%
Clarity in assessment explanation	0%	60%	40%
Development intellectual skills through the course	0%	50%	50%
Course contribution to overall learning experience	0%	60%	40%

quantitative research on outcome-based teaching and learning in computer science education at post-secondary level. OBA can be effective, and perhaps more effective approaches are yet to be found.

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Gary K. W. Wong (S’04) received the B.Sc. degree, *Magna Cum Laude*, in Computer Science and Mathematics (Double Majors) from Brigham Young University Hawaii (BYUH), the United States, in 2006. He also received the M.Phil. degree in Electronic and Computer Engineering from the Hong Kong University of Science and Technology (HKUST), Hong Kong, China, in 2009. He is currently pursuing a Ph.D. in Computer Science at City University of Hong Kong. He is also an Assistant College Lecturer in the IT/Math Subject group at the Community College at Lingnan University.

His research interests include mobile and pervasive computing, wireless communication and networks, and wireless quality-of-service (QoS) provisioning for mobile networks. Also, he is interested in computer science education, educational leadership and policy, and higher education.

Mr. Wong received the *Upsilon Pi Epsilon* (UPE) honorable award in 2003, and two UPE scholarships in 2004 and 2005 consecutively. He was a student member of the ACM since 2003, a student member of the IEEE since 2004, and a graduate student member of the IEEE since 2007. He has served as a technical reviewer for various conferences and journals including IEEE Trans. of Wireless Communications, IEEE Trans. of Multimedia, and IEEE Trans. of Vehicular Technology. He is now an IEEE member, ACM professional member, a member of the IEEE Communications Society, and a member of the ACM SIGMOBILE.

H. Y. Cheung received the B.Sc. and MPhil. in Physics from the Hong Kong University of Science and Technology (HKUST) with focus on scientific computation. He is currently a Senior College Lecturer and the Head of Business Programmes at the Community College at Lingnan University in Hong Kong, China.

Mr. Cheung’s research interests include mathematical modeling, computer simulation of granular nano-materials, as well as genetic algorithm and evolutionary programming for solving multi-objective optimization problems. Moreover, as an education practitioner with over 6 years of experience teaching IT, mathematics and science subjects at the sub-degree level in Hong Kong, Mr. Cheung is also interested in learning and researching about outcomes-based education and the adoption and promotion of IT in post-secondary education.