ENGINEERING EDUCATION IN HONG KONG SECONDARY SCHOOLS – THE APPLIED LEARNING COURSE APPROACH

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Abstract

In Hong Kong, the efficacy of engineering education in secondary schools is always difficult to measure. This is mainly because there are limited engineering-oriented subjects and few teachers with backgrounds in engineering. Engineering education is often infused into the curriculum of secondary schools through science, technology and mathematics (STM) subjects. Students' involvement in engineering related school-based and extracurricular activities are limited. Only a few technical schools in Hong Kong are offering engineering-oriented subjects such as Electronics & Electricity and Technology Fundamentals.

Some previous studies have identified that the lack of engineering education in secondary schools may affect the students' aspiration to become engineers, while some studies have investigated the gap of engineering education at the secondary-tertiary interface. Likewise, many post-industrial societies are facing the same challenges as Hong Kong, which have strong demand for engineers but struggled with the low intake of engineering programmes in higher education and subsequent careers.

This paper responds to the addressed issues of engineering education in Hong Kong secondary schools and performs a practical study of the effectiveness of Applied Learning Courses (ApL), which are introduced to diversify the curriculum of senior secondary students by the Education Bureau of the Hong Kong SAR government. The design of ApL emphasizes the development of fundamental skill set, career-related competencies and generic skills of students, and explore their career aspirations and orientation for lifelong learning.

The overall curriculum design and pedagogy of two selected ApL courses of engineering (electrical & energy engineering and digital construction) will be studied to investigate how the courses can instil engineering knowledge, provide practical 'hands-on' experiences and enhance engineering aspirations among secondary school students.

The study also provides recommendations on improving the design and structure of ApL courses as an approach of effective engineering education in secondary schools.

Keywords: *engineering education, applied learning, curriculum and pedagogy, secondary schools, engineering aspiration*

Introduction

In Hong Kong, engineering education is not included on its own in mainstream secondary curricula. It is typically infused and introduced as part of the science curriculum. In senior secondary level, students can choose to specialize in science and technology, and take courses in mathematics, physics and chemistry, which form the foundation for further studies in engineering.

However, although with a strong exposure to these science, technology and mathematics (STM) subjects, previous studies have found that students do not show significant aspirations to pursue further studies in engineering and to become engineers eventually (Kutnick et al., 2018).

The reform of secondary education in Hong Kong has made the situation even worse, in which the number of technical secondary schools has declined, which means that engineering-oriented subjects are rarely offered in secondary education now.

Secondary school students, however, are always provided with a range of opportunities to acquire knowledge in engineering, such as, school-based extra-curriculum activities, open competitions organized by universities or other organizations, and career talks by professional institutions. How these can enhance the students' aspiration for further studies in engineering and to become engineers, are subject to further investigation.

Aim and Objectives

The aim of this paper is to propose an effective mechanism of engineering education in secondary

schools by conducting a practical case study of Applied Learning courses (ApL) in current secondary school curriculum in Hong Kong.

The objectives of this paper are to briefly review the existing problems of engineering education in Hong Kong secondary schools, which affect the aspirations of the students to become engineers; to study the effectiveness of the implementation of ApL in secondary school curriculum; and to provide recommendations on improving the design and structure of ApL courses as an approach of effective engineering education in secondary schools.

Literature Review

Kutnick et al. (2018) conducted a survey among secondary school students on their aspirations to become engineers in Hong Kong, the results showed that the responding students were normally not provided with significant support by the school-based engineering opportunities to contribute to their aspirations. In the study, some contributory factors to aspire the youth to become engineers were also discussed, such as practical activities, encouragement by teachers and parents, motivation to engage in engineering activities, perception of engineers and engineering efficacy.

Other studies on engineering education in secondary schools, such as by Purzer S. & Shelley Mack (2018), Case J. et al. (2013) and Millham, R.et al. (2014), have focused on how the curriculum design, soft skill training and learning style could assist in effective teaching and learning of engineering knowledge. They shared the common view that engineering education can be effectively promoted through science, technology and mathematics (STM) subjects of the curriculum.

Purzer and Shelly (2018) further suggested that the abilities in problem-solving, critical thinking, and creativity are critical in developing engineering education, as well as the importance of integrated learning as the basis of engineering knowledge. Felder (2012) has also stated that traditional lecture-based instruction and monodirectional knowledge sharing is no longer effective in enhancing students' engineering aspirations.

Moore, T. J. et al. (2014) outlined a framework of engineering education along the learning path of secondary school. The framework was designed to inform the integration of engineering within the secondary school curricula. Some indicators are proposed such as "process of design", "engineering thinking", "engineering tools" and "ethics" etc.

The above literature has offered discussion on the design of effective engineering education in secondary schools, through curriculum design, pedagogy, assessment tasks and learning activities. The case studies in the paper will also focus on these areas.

Materials and Methods of Study

The Education Bureau of Hong Kong SAR Government has introduced ApL courses as elective subjects to diversify the senior secondary curriculum. The design of ApL emphasizes the development of fundamental skill set, career-related competencies and generic skills of students, and explore their career aspirations and orientation for lifelong learning. (Education Bureau, 2023)

While there are limited studies evaluating the acheivement of the general objectives of ApL, this study focuses on how ApL can contribute to engineering education in secondary schools. Two ApL courses in engineering, which are entitled "Electrical and Energy Engineering" and "Digital Construction" are therefore selected as case studies.

In line with the preivous studies on engineering education in secondary schools, the case studies would also focus on curriculum design, pedagogy, assessment tasks and learning activities.

Case Studies

Two ApL courses operated by Vocational Training Council (VTC) are selected for the case studies, which are entitled "Electrical and Energy Engineering" (EEE) and "Digital Construction" (DC). Among all the ApL courses provided to senior secondary school students, these courses are the two major engineering-related ones.

Secondary schools and their students are offered the opportunities to select ApL courses, which can be embedded into the school curriculum. Classes are usually conducted in school hours or in VTC during weekends.

Apart from normal classroom learning, students are provided with various enigneering-related activities, ranging from company and facilities visits, career talks and guest lectures, etc.

Basic information of the two courses are listed in Table 1.

	EEE	**DC**
No. of Module	3	4
Project based Module	1	1
Contact Hours	180	180
No. of Assessment Task	7	6

Table 1. Basic course information

Curriculum Design

ApL courses are desgined for secondary school students, and hence the purpose is to develop the fundamental skill sets and students' career-related exposure. Essentially, the curriculum design of the courses are guided by five curriculum pillars, namely career-related competencies, foundation skills, thinking skills, people skills and values and attitudes.

In addtion to the five guiding principles of curriculum design, the two courses also have their distinct design parameters.

The EEE course enables students to understand fundamental theories and concepts, develop their generic skills, and address their further studies and career aspirations in the electrical and energy engineering industry. While the DC course aims to provide students with basic knowledge about construction technology.

The learning outcomes of the two courses are demonstrated as:

Electrical and Energy Engineering (EEE)

1. analyse the general profile of the electrical and energy engineering industry, and its latest development;

2. apply the basic principles and techniques of electrical engineering, in particular the knowledge of energy efficiency enhancement to formulate engineering solutions;

3. integrate knowledge and skills in electrical and energy engineering industry, including work ethics and social responsibilities, occupational safety and sustainable development, as well as communication and problem solving skills;

4. interpret the latest development and achievements in the related engineering fields.

Digital Construction (DC)

1. appreciate the general environment of the construction industry;

2. recognise the latest development and achievements in construction technology in the related field;

3. apply the basic principles and techniques of construction technology to formulate solutions;

4. design and implement projects with integration of knowledge and skills in creative thinking, communication skills and problem-solving skills, with due consideration and a basic understanding of the importance of work ethics, safety as well as sustainable development;

5. demonstrate positive values and attitudes towards the construction industry;

6. develop self-understanding for further studies and career development in the related field.

The modules included in the curriculum are showed in below tables.

	Module Title
1	Overview of Electrical and Energy Engineering
2	Utilisation of Electrical Energy
3	Energy Resources and Efficiency

Table 2. List of modules in ApL Electrical and Energy Engineering

	Module Title
1	Understanding Construction Industry
2	Introduction to Construction Technology
3	Application of Construction Software and Equipment
4	Construction Technology Project

Table 3. List of modules in ApL Digital Construciton

Both courses provide an overview of the industries in their first modules, and go on to teach students the fundamental theories and concepts through knoweldge sharing, application and practice. Students are facilitated to integrate the knowledge learned and acquired in completing a study-based project at the end of the course.

The courses are designed to complete in two school years. Throughout the learning journey, students are encouraged to acquire an early understanding of the engineering theories and practice, equipped with soft skills like problem-solving, critical thinking and communication. Most importantly, the strong involvement of students in engineering based activities can effecitvely enhance students' interest and aspirations to pursue further studies in engineering.

Pedagogy

The courses provide a simulated learning environment for students. This is supported with training facilities like electrical project laboratory, electrical installation and repair training workshop, Building Information Modelling (BIM) and geometrics computing laboratory and construction project studio, etc.

Several types of teaching and learning activities are introduced, which are summarized in the table below.

	Type of teaching and learning activity	**Purpose**
1	Classroom teaching	Knowledge sharing and delivery
2	Group discussion and presentation	Reflection of knowledge acquired and sharing of ideas
3	Experiment and workshop	Practical training and application of solutions to practical tasks
4	Project	Knowledge integration and implementation
5	Company and facilities visit	Appreciation of real life practice and know-how

Table 4. Teaching and learning activities

Problem-based learning and active student engagement are purposefully injected in most of the teaching and learning activities. For example, problem-based learning is being implemented in integrated project workshops, in which students are assigned with tasks without a definite solution. Students are encouraged to design, develop and discuss the solutions, by defining

and interpreting the problems. The role of the tutor is to facilitate learning by supporting, guiding, and monitoring the learning process.

Students are engaged to actively participate in classes and shared their ideas openly. They are often formed in groups to work like a team to enhance discussion and communication.

Assessments

Both courses include a number of assessment tasks, which are evenly distributed across the course. The types of assessment tasks are listed in the table below.

	Type of assessment task	Purpose
1	Test	Examination of knowledge gained
2	Study report	Assessment of information gathering, analysis and writing abilities
3	Presentation	Assessment of communication skills and question-handling abilities
4	Project	Assessment of overall integration of theory and practice, and problem solving skills

Table 5. Assessment Tasks

The assessment tasks are designed to assess students' level of understanding and the attainment of learning outcomes. Feedback on assessment tasks would be given for self-assessing and improvements.

Results and Discussion

Based on the information and findings gathered from the case studies, the effectiveness of the two ApL courses of engineering is evaluated in the following five criteria.

(1) Design Process
(2) Applications of engineering concepts
(3) Problem solving
(4) Teamwork and communication related to engineering
(5) Exposure to engineering environment

These five evaluation criteria are essential in the framework of engineering education and are previously identified by Felder (2012), Moore (2014), Purzer and Shelly (2018).

Design Process

Design process is crucial in defining the issue and formulating solution in engineering tasks. It involves the process of preparation, planning and evaluating the engineering design. In the ApL courses, students are provided with different kinds of engineering tasks which require the design input of students. For example, in EEE course, students are asked to design the electrical energy system. In DC course, students are asked to design new building structure by using BIM software.

Along the design process, students can learn how to identify the issue, generate ideas and plan the implementation process. Each design is subject to review and verification. If the design does not achieve the intended outcome, the process of redesign will follow. It largely resembles the thinking process of an engineer.

Applications of engineering concepts

Throughout the courses, students have many chances to acquire and apply engineering concepts. These range from fundamental engineering knowledge, actual engineering practice, new technology and advancement of the engineering professions, and sharing of practical experiences by professional engineers.

Applications of engineering concepts are usually a combination of knowledge and practice. For example, in DC course, when students are asked to design the site supervision system, they would first identify the existing problems of construction site supervision, and suggest feasible solutions by using digital applications.

Problem solving

Engineers are always ready to tackle problems, and provide solutions in different aspects of engineering professions. The ability of problem solving is essential in engineering eduction. (Jonassen, 2006)

The courses guide students to develop the mindset of problem solving. For example, in EEE course, students are asked to tackle problems related to electrical installation and safety under the client's and statutory requirements. Problem-based learning also facilities students to familiarize with the process and strategies in solving problems.

Teamwork and communication related to engineering

Teamwork is considered a key skill in engineering. A number of attributes such as effective communication, constructive feedback and leadership are widely regarded in successful teamwork. (Chowdhury, 2019)

Students often form into small teams to brainstrom, discuss and analyse the given tasks. In the integrated project module, students can demonstrate the abilities of communication, feedback and leadership through group discussion, report writing and presentation.

Exposure to engineering environment

A number of teaching and learning activities are organized to enhance the learning experiences of students. Among them, some activities allow students to interact with the workplace environment of engineering industry, such as company and facilities visits, career talks and guest lectures.

The courses help students better prepare themselves for further studies and career opportunities in

engineering. Outstanding students may have internship opportunities in engineering and construction companies.

Conclusions

This paper proposes and evaluates an effective mechanism to fill the gap of engineering education in secondary schools. Two ApL courses in engineering are studied to investigate their effectiveness to aspire students' interest in engineering, for potential pursuing of further studies and career choices. The curriculum design, pedagogy, assessment tasks and learning activities of the courses are studied.

By matching the information and findings of case studies with five evaluation criteria, the effectiveness of the ApL courses are affirmed.

These are reflected in the following aspects:

1. allows students to develop a basic understanding in engineering and the potential interest into further study and career choice;

2. enables students to learn fundamental theoretical knowledge as well as practical and generic skills in engineering;

3. provides valuable and specific engineering education in secondary curriculum by teaching basic engineering knowledge and a wide range of engineer competencies such as problem solving, application of engineering concenpt, teamwork and communication skills;

4. adopts a variety of pedagogies to motivate students to learn. These includes group discussion and presentation, experiment and workshops, project works, company and facilities visits, simulated assessment tasks.

Recommendations

With regards to the affirmative effect by the ApL approach in engineering education, there are a number of recommendations on improving the design and structure of ApL courses.

1. More interactions between the ApL courses and science, technology and mathematics (STM) subjects. This would help students to connect the knowledge from STM subjects to engineering. For example, in setting assessment tasks of the ApL courses, students can be asked to make use of generic STM knowledge.

2. Support from the engineering industry is essential to bring the most advanced knowledge and practice into the course curriculum. It can be guest lectures, company and facilities visits, scholarships and internship. Professional engineers can also be invited to contribute feedback to curriculum development.

3. Advanced technology in engineering such as artificial intelligence, robotics, internet of things and design software should be largely adopted to arouse the interest of students in engineering.

4. Pedagogies such as technology enhanced learning, project based learning and active student engagement can be strengthened and adopted to the courses.

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