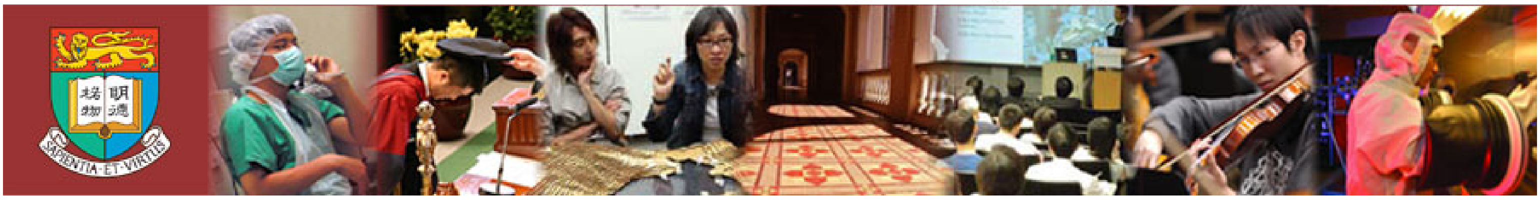

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# AC 2012-5321: ENGINEERING EDUCATION OPPORTUNITIES, PERCEPTION, AND CAREER CHOICE OF SECONDARY SCHOOL STUDENTS IN HONG KONG SAR, CHINA

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# Engineering education opportunities, perception, and career choice of secondary school students in Hong Kong SAR, China


## Abstract

This paper presents an investigation into engineering education opportunities and engagement among secondary school students in Hong Kong SAR, China (HK). We adapted and validated an international questionnaire and executed it in HK secondary schools. The questionnaire is designed to identify pedagogy, students' perception, and experience (formal and informal) of engineering education, and measure their effects on students' career choice in engineering. We investigate how do factors like age, gender, family background (local versus new immigrants), subjects taken at school, and perceptions of the engineering profession affect their career choice in engineering. Identifying factors affecting young people's career choice in engineering is interesting as HK is in an early post-industrial position. Such study can provide an excellent comparative example to contrast between post-industrial societies such as the United States and industrializing societies such as other cities in the mainland China.


## Introduction

As a major city and financial center in Greater China and Asia Pacific, Hong Kong (HK) borders industrializing and post-industrial cultures. The economy is at a time of increased need for technically- and university-trained engineers. HK has a history of innovatory engineering skills extending from traditional manufacturing and construction to a large service and financial industry. However, it does not help to overcome reducing take-up of engineering-oriented courses at secondary school and university that characterize post-industrial cultures. Similar to the situation in North America, contextually, studies of higher education in HK show a decline in take-up of engineering by local students. This decline in engineering study and careers in HK parallels STEM-based choices in western countries at a time when there is a growing need for engineers to maintain industry and the economy. The decline in HK contrasts with: the range of opportunities to study technology/engineering in upper levels of secondary and vocational schools; extra-curricular opportunities offered by engineering institutions and manufacturing organizations; and high levels of engineering interest among mainland (Chinese) and other immigrant students. Understanding the take-up of engineering opportunities by secondary students in HK must acknowledge that students are active participants in their course/career choices – but choice will be constrained by the organizational, pedagogic and personal/familial opportunities affecting each student.

Since the new millennium, a number of focal changes have taken place. In western countries came the realization of an increased need for engineers and university entrance studies that identified a decline in engineering entrants. Further studies have identified the limited presence of engineering in STEM subjects and the limited opportunities to take-up a career in engineering by women. International STEM comparisons also noted national/cultural differences in the take-up of engineering courses at secondary school and career choice (ex. Relevance of Science Education [RoSE], TIMSS and PISA studies described by John & Ju[1]); where North America, Northern and Central Europe, Japan and Korea show the drop-off in engineering career choice while Southern Europe, New European countries (ex. Latvia, Estonia) and China show an increased take-up. These further studies have forced a change in orientation of engineering education studies to a recognition of the need to: a) make engineering educational opportunities and careers more visible to the public – especially at in schools and at an age level before career decisions are made; b) develop an understanding about personal experience and choice regarding engineering education courses and careers which consider the role of pedagogy and teacher support; and c) move to an 'engineering education research' orientation that is both representative of particular societies and rigorous. The need for these changes has only just been identified[2].

## Engineering Education and Situations in Hong Kong

Understanding why only a limited number of students choose engineering for study/career poses a problem for HK. From the limited information available, we note that engineering cannot be studied in secondary schools until students enter Form 4 (age 15+) although students access technology, science and mathematics from the start of secondary schooling (Table 1). Access to an early understanding of engineering is, thus, likely to be derived through: home contacts, limited exposure in science/mathematics/technology curricula (mainly taught by non-engineers), or extra-curricular initiatives.

Table 1: Provision of Secondary School Engineering courses in Hong Kong

| TYPE OF SCHOOL | MALE ONLY (n=32) | | FEMALE ONLY (n=41) | | CO-ED (n=384) | | TOTAL (n=457) | |
|---|---|---|---|---|---|---|---|---|
| | Lower Yrs (S1-S3) | Upper Yrs (S4-S6) | Lower Yrs (S1-S3) | Upper Yrs (S4-S6) | Lower Yrs (S1-S3) | Upper Yrs (S4-S6) | Lower Yrs (S1-S3) | Upper Yrs (S4-S6) |
| **SUBJECT** | | | | | | | | |
| *Automobile Tech (S1-S3)* | 0% | | 0% | | 0% | | 0% | |
| *Computer Lit (S1-S3)* | 96.88% | | 87.80% | | 87.50% | | 88.18% | |
| *D & T (S1-S3)* | 31.25% | | 2.44% | | 55.47% | | 49.02% | |
| *Electronics (S1-S3)* | 6.25% | | 0% | | 1.30% | | 1.53% | |
| *Home Ec / Tech & Living (S1-S3)* | 6.25% | | 95.12% | | 60.42% | | 59.74% | |
| *Tech Funda (S1-S3)* | 0% | | 0% | | 1.82% | | 1.53% | |
| | | | | | | | | |
| *Design & Applied Technology (NSS)* | | 9.38% | | 2.44% | | 12.24% | | 11.16% |
| *Info & Com Tech (NSS)* | | 96.88% | | 92.68% | | 94.27% | | 94.31% |
| *Tech& Living (NSS)* | | 0% | | 24.39% | | 4.43% | | 5.91% |
| *NSS Applied Learning (ApL)*1* | | 37.50% | | 31.71% | | 36.20% | | 35.89% |

(Notes: D & T stands for Design and Technology; NSS stands for New Secondary School curriculum, equivalent to Grade 10 to 12 in US)

Take-up of engineering subjects in HK parallels western STEM studies (in the USA and UK[3,4] and Pacific/Asian countries such as South Korea[1,5] – where decreasing numbers of top students choose engineering subjects at school or higher education[6,7] in spite of its increasing importance for the economic health of nations. Low take-up of engineering courses does not indicate low exposure to engineering during secondary schooling though. In HK, technology subjects account for 8% of curriculum time[8]; and similar opportunities are provided elsewhere via K-12 programmes in the USA[9] and outreach in the UK[10]. Lack of rigorous engineering education studies in secondary schools in HK does not allow an immediate explanation of the gap between opportunity and take-up of engineering education.

In light of limited studies in HK, we identify some key issues raised in western engineering and STEM studies:

1. Most school children choose careers before they turn 14 – before engagement with engineering courses in HK and elsewhere[1,11,12];

2. although secondary students have early access to science, technology and mathematics, both Holman[9] and Katehi et al.[13] to refer engineering's true representation in schools as STEM – noting subject/career choice are strongly affected by non-school, extra-curricular, family and media influences;

3. an survey[14] of Year 9 (age 14+) children's career choices identified the importance of subject teachers encouraging subject/career choice and found that science teachers were unlikely to have an engineering background or act as a career advisor with regard to engineering;

4. engineering education teachers are unlikely to be engineers and have little knowledge of engineering[9,15];

5. these teachers often rely on 'transmission' pedagogy[3] when current (higher education) studies identify that engineering demands active skills of efficacy, innovation and entrepreneurship[16];

6. access to applied problem solving and interpersonal skills in the Design & Technology curriculum[17] may enhance aspirations if sympathetic teacher allow engineering topics to enter the curriculum in an experiential manner[18,19];

7. pedagogy that encourages engagement and positive attitudinal development within a subject[20] may have a central role in enhancing engineering as a subject/career choice at school level but there is little current evidence that identifies a relevant pedagogy for engineering aside from: 'developmentally appropriate' recommendations[9] and the need to move beyond 'plan and do' constructions and contests by the inclusion of reflection after activities[21];

8. there are high participation rates for ethnic minorities but not females[22]; and

9. engineering take-up tends to be explained by home and cultural background[23] – arising during the life-course rather than via a 'linear' school-dominated progression[24].

Finally, very few evaluations of school-based engineering education have the rigor of control/comparisons and often focus on numbers attending rather than impact on course/career choice[25]. From the above studies, we can surmise there is little understanding of opportunities, support and effective pedagogy associated with engineering education in HK or elsewhere. Theoretically, we are left with simplistic explanations for choice of engineering as a subject/career characterized by: home, school-type, teacher, extra-curricular activities, and cultural perceptions.

**Research Questions and Method**

In light of need to develop the above aspects of engineering education research in HK, this study draws upon local information and the international literature to inquire on the following research questions:

1. What is the current situation of engineering education at secondary school in HK, with regard to: exposure to engineering education experiences; effects of school- and non-school-based engineering experiences; and perceptions/attitudes of engineers including aspects of planned behaviour, efficacy, entrepreneurship and teamwork?

2. With regard to (1), are there any differences exist with regard to student gender, minority and home background status?

3. What are the relationship between engineering orientation (efficacy, academic choice, and career orientation) and various engineering education experience?

Instrument

A questionnaire designed for engineering students in higher education was adapted and extended for use in secondary schools in HK. Questions sought information on: family/home engineering and demographics; course choice in schools; extra-curricular activities; perceptions of engineers; efficacy, teamwork, entrepreneurship; career choice. Measurement covered 7 scales: formal or active learning approaches to engineering (LEARNING, 5 dimensions, 11 items; Cronbach's alpha = .63), amount of curriculum-based engineering experience (CURRICULUM, 3 dimensions, 15 items; Cronbach's alpha = .69), amount of non-curriculum-based engineering experience (EXPERIENCE, 5 dimensions, 22 items; Cronbach's alpha = .75), people who support engineering (PEOPLE, 3 dimensions, 9 items; Cronbach's alpha = .53), perceptions of engineers (PERCEPTION, 5 dimensions, 15 items; Cronbach's alpha = .81), engineering efficacy (EFFICACY, 2 dimensions, 19 items; Cronbach's alpha = .62) and engineering orientation (ORIENTATION, as outcome consists of 3 variables: Interest, Academic, and Career; Cronbach's alpha = .75). Questionnaires were back-translated, pre-piloted and piloted with secondary school students.

Sample

Data was collected from 726 secondary school students (455 girls and 271 boys; 197 12-year-old, 205 14-year-old, 165 16 year-old, and 159 17-year-old; 570 Chinese born in Hong Kong, 99 immigrants from Mainland China, 44 minorities including mainly South Asians/Southeast Asians); a sample size calculation based on a 95% Confidence Level and 4 % Confidence Interval for a secondary school population of 469,000 suggests a sample of 599). A limited stratified, cross-sectional and clustered sample was identified to allow for comparisons of: school attainment, single-sex/co-educational school; student age (12, 14, 16, and 17), and orientation to engineering in the curriculum.

Analysis

Quantitative survey had been performed to seek information on: family/home engineering and demographics; course choice in schools; extra-curricular activities; perceptions of engineers; efficacy, teamwork, entrepreneurship; career choice. Analyses of variance (ANOVAs) were performed to find out any significant differences between groups (gender, age, and family background) on the 7 scales. A structural equation model (SEM) was constructed to validate the relationship between the 6 scales (LEARNING, CURRICULUM, EXPERIENCE, PEOPLE, PERCEPTION, EFFICACY) and the outcome (engineering ORIENTATION). The SEM model has also been tested for fitness.

## Results

### Means and Differences by Gender, Age, and Family Background

Mean scores for the 6 scales and 3 outcome variables are summarized in Table 2. Analyses were conducted to examine whether there were differences for gender, age, and family background (Hong Kong born Chinese, mainland immigrants, and minority).

Table 2
Mean Scores by Groups

| | Gender | | Age (years) | | | | Family background | | |
|---|---|---|---|---|---|---|---|---|---|
| Scale/Variable | Girls | Boys | 12 | 14 | 16 | 17 | HK | Mainland | Minorities |
| LEARNING | 3.78 | 3.80 | 3.90* | 3.81* | 3.73* | 3.65* | 3.79 | 3.66 | 3.96 |
| CURRICULUM | 2.43*** | 2.66*** | 2.44 | 2.50 | 2.51 | 2.54 | 2.47 | 2.66 | 2.51 |
| EXPERIENCE | 3.20*** | 2.83*** | 3.09 | 3.10 | 2.97 | 3.10 | 3.11 | 2.87 | 3.15 |
| PEOPLE | 1.44*** | 1.96*** | 1.49* | 1.55* | 1.81* | 1.61* | 1.55*** | 2.03*** | 1.47*** |
| PERCEPTION | 3.61* | 3.46* | 3.77*** | 3.65*** | 3.44*** | 3.29*** | 3.56 | 3.54 | 3.82 |
| EFFICACY | 4.04* | 3.90* | 3.88 | 4.03 | 4.00 | 4.08 | 3.98 | 4.09 | 4.10 |
| ORIENTATION (Interest) | 3.06 | 3.07 | 2.96 | 3.19 | 3.01 | 3.06 | 3.06 | 3.11 | 3.03 |
| ORIENTATION (Academic) | 2.75* | 2.95* | 2.73* | 3.02* | 2.74* | 2.74* | 2.81 | 2.84 | 2.79 |
| ORIENTATION (Career) | 2.63 | 2.79 | 1.50 | 1.48 | 1.49 | 1.45 | 2.62** | 3.11** | 2.43** |

Notes: ***significant at the .001 level (2-tailed); **significant at the .01 level (2-tailed); * significant at the .05 level (2-tailed).

For comparison between girls and boys, significant differences were found in CURRICULUM ($F(1, 714) = 13.87$, $p < .001$, $\eta^2 = .019$): girls ($M = 2.43$) had less formal curriculum experience than boys ($M = 2.66$); EXPERIENCE ($F(1, 714) = 17.12$, $p < .001$, $\eta^2 = .023$): girls ($M = 3.20$) participated in more non-curriculum-based experience than boys ($M = 2.83$); PEOPLE ($F(1, 714) = 44.07$, $p < .001$, $\eta^2 = .058$): boys ($M = 1.96$) received stronger encouragements than girls ($M = 1.44$); PERCEPTION ($F(1, 714) = 4.83$, $p < .05$, $\eta^2 = .007$): girls ($M = 3.61$) had a more positive perception of engineering than boys ($M = 3.46$); EFFICACY ($F(1, 714) = 4.54$, $p < .05$, $\eta^2 = .006$): girls ($M = 4.04$) had higher engineering efficacy than boys ($M = 3.90$); and Academic ($F(1, 714) = 4.539$, $p < .05$, $\eta^2 = .005$): girls ($M = 2.75$) indicated lower incentives in choosing engineering as their academic choice than boys ($M = 2.95$). There were no significant differences in engineering interests and career goal between boys and girls.

In comparing age groups, significant differences were found in: PERCEPTION among age groups ($F(3, 722) = 11.45$, $p < .001$, $\eta^2 = .045$): younger students indicated a more positive perception of engineering ($M = 3.77$) than older students ($M = 3.29$); the most positive scores in

Academic ($F(3,722) = 2.47$, $p < .05$, $\eta^2 = .010$) found at age of 14 ($M = 3.02$); but the most positive scores in PEOPLE ($F(3,722) = 3.55$, $p < .05$, $\eta^2 = .015$) at age of 16 ($M = 1.81$, $p < .05$).

In terms of family background, significant differences were found in: PEOPLE ($F(2, 710) = 10.84$, $p < .001$, $\eta^2 = .030$) and Career ($F(2, 710) = 5.53$, $p < .01$, $\eta^2 = .015$), with immigrants from mainland China ($M = 2.03$ and $M = 3.11$, respectively) scoring higher than Chinese born in Hong Kong ($M = 1.55$ and $M = 2.62$) and minorities ($M = 1.47$ and $M = 2.43$).

<u>Engineering Experiences, Perception and Career Choice</u>

A structural equation model (SEM) was conducted to provide a coherent picture, and to test a model based on the hypothesis that engineering experience (gained from multiple sources including students' own learning approaches, courses from formal curriculum, non-curriculum-based engineering activities, and people including teachers, parents, and peers) affect students' engineering perception and efficacy, which in return affect students' engineering orientation.

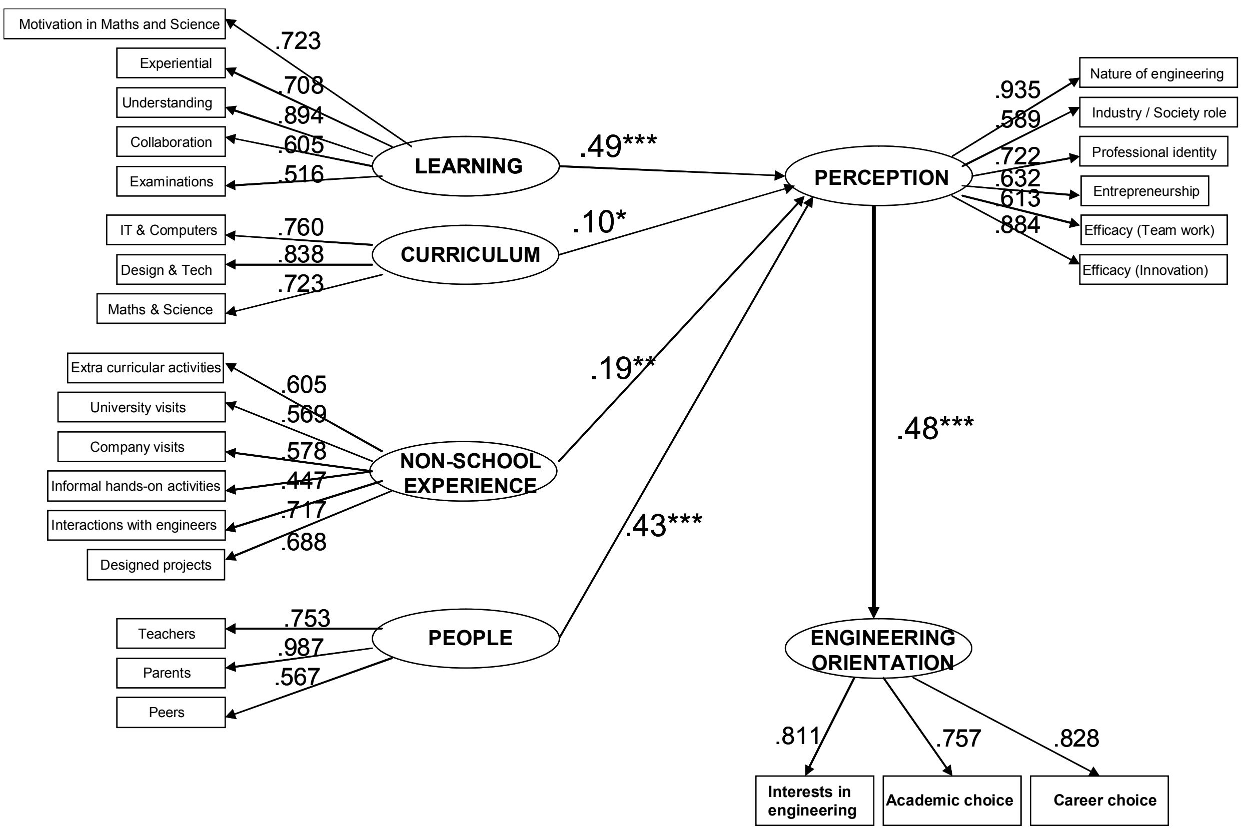


**Fig. 1.** A structural equation model of learning approaches, curriculum-based and non-curriculum-based engineering experiences, people influence, perception of engineering and engineering orientation. (** indicates significance at .01 level, * indicates significance at .001 level)

The model as depicted in Figure 1 showed standardized solutions of paths. Testing of the model yields indices (CFI = .933, TLI = .910, GFI = .921, RMSEA = .058, SRMR = .077) that indicate a good fit.

**Discussion**

Current situation of engineering education at secondary school in HK

Drawn from the sample in HK, our results identify that interest and participation in engineering education can be found in across age groups – and pertain to a variety of engineering experience and engagement. Academic and career choices are highly related to students' perception of engineering, which is highly related to students' learning approaches. Age differences identified also indicated that students' perception of engineering became less positive along age. Align with the results from European and western countries, the time when students having a strongest incentive in choosing engineering as their academic choice is 14. Outreach courses and engineering summer camps in HK, often being offered to students at secondary 6 (Grade 12), however, may be offered too late in secondary school stage and 'miss' the younger student interest. Traditional science/mathematical 'training' as a background for engineering may not be as relevant of a pedagogy as experiential learning and hands on activities.

Girls and boys in HK basically have no significant differences in terms of engineering perception, interest and efficacy; however, girls received less curriculum-based engineering experience and encouragement from teachers and parents and may 'avoid' choosing engineering for university study. It is also identify from our study that girls meeting female engineers within a single-sex context may offer more encouragement than a mixed-sex context (not shown in SEM).

Immigrant students (from China) received stronger encouragement from teachers and parents in pursuing engineering studies and indicated a stronger incentive in choosing an engineering career. These findings: widen our understanding of student choice of engineering courses/careers from limited engineering exposure that may be presented too late in the school years and at too abstract of a level to engage student understanding; and set a basis for qualitative studies focusing on individual students and pedagogic experience in HK as well as comparisons with China and across the Pacific region to tease out culturally defined engineering aspirations.

Relationship between engineering orientation and various engineering education experience

One would expect that HK's top ratings in science and mathematics (see TIMSS[26] and PISA[27]) would provide background and encouragement for high levels of interest in engineering courses/careers. Yet, recent university entrance analyses show that engineering is in a fluid situation – with a rapid decline in local students mitigated by an increase in minority/mainland Chinese students[6,7].

Our SEM indicates how factors as students' learning approaches, curriculum-based and non-curriculum-based engineering experiences, and people influence affect students' engineering orientation, mediated by their engineering perception. It is shown that engineering perception is strongly significantly related to engineering orientation ($r = .48$, $p < .001$). With many opportunities in schools and a strong basis in traditional subjects that prepare students for engagement in engineering, it is however, found that curriculum exposure only has a relatively weak effect on students' engineering orientation ($r = .10$, $p < .05$). Yet, it is interested to found out that student learning (which was measured in terms of motivation, approaches to experiential learning, understanding, collaboration, as well as examinations) is significantly related to engineering perception ($r = .49$, $p < .001$). Similar level of significance is also indicated in the people factor ($r = .43$, $p < .001$); it is particularly align with the Chinese traditional culture that parents and teachers contribute very significantly to students' engineering perception. It is noted that non-school-based engineering experience (which take the forms of university engineering department visits, company visits and engineering outreaching of various kinds) also contribute to a positive engineering perception ($r = .19$, $p < .005$), though it is less significant when compare to other factors.

## Conclusion

The current study has identified the current situation of engineering education at secondary school in HK, with regard to factors such as exposure to engineering education experiences; effects of school- and non-school-based engineering experiences; and perceptions/attitudes of engineers including aspects of planned behaviour, efficacy, entrepreneurship and teamwork. We also identify differences exist with regard to student gender, minority and home background status. A structural equation model has also been constructed to confirm about the relationship between engineering orientation (efficacy, academic choice, and career orientation) and various engineering education experience.

Acknowledging differences between demand and engagement within the cultural crux of HK, this study undertake linked studies of educational, pedagogic and cultural/theoretical importance. While a number of North American and Northern European studies[10,19] concerning engineering educational innovations in schools and universities (see review by Borrego & Bernhart[2]) have been initiated, there are no systematic or representative reviews of the impact of engineering education opportunities on students' course and career choices in HK. The current study provides a systematic/representative study of school-based engineering education engagement and its relation to course/career impact, an exploration of pedagogic activities associated with engineering engagement, and provides a basis for potential cultural comparisons to industrializing (e.g. Chinese) and post-industrial (e.g. US and England) societies. Results will also confirm a move away from non-rigorous engineering education studies to systematic engineering education research.

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