Attitudes and aspirations regarding engineering among Chinese secondary school students: Comparisons between industrialising and post-industrial geo-engineering regions of Mainland China and Hong Kong[1]

Peter Kutnick[a,c,x], Zhiyong Zhu[b], Cecilia Chan[c], Rosanna YY Chan[d] with Betty PY Lee[c] and Veronica Ka Wai Lai[d]

[a]King's College London, [b]Beijing Normal University, [c]University of Hong Kong,[d] Chinese University of Hong Kong

Peter Kutnick, School of Education Communication & Society, King's College London, Franklin-Wilkins Building, Waterloo Road, London SE1 9NH, UK, +44 (0) 2078483183, peter.kutnick@kcl.ac.uk, and University of Hong Kong, Faculty of Education
Zhiyong Zhu, College of Education Administration, Beijing Normal University, Yingdong Education Building, 19 Xinjiekou Wai Street, Beijing, 100875, China, +86 1058802990, zzy@bnu.edu.cn
Cecilia Chan, Centre for the Enhancement of Teaching and Learning, University of Hong Kong, Pokfulam Road, Hong Kong SAR, +852 3917 8534, Cecilia.Chan@cetl.hku.hk
Rosanna YY Chan, Department of Information Engineering, Chinese University of Hong Kong, Ho Sin Hang Engineering Building, Shatin NT, Hong Kong SAR, +852 39438483, yychan@ie.cuhk.edu.hk
Betty PY Lee, Faculty of Education, University of Hong Kong, Pokfulam Road, Hong Kong SAR, +852 28592544, bettylee_hku@yahoo.com.hk
Veronica Ka Wai Lai, Department of Anaesthesia and Intensive Care, Chinese University of Hong Kong, Prince of Wales Hospital, Shatin NT, Hong Kong SAR, +852 23621912, veronicalai@linl.cuhk.edu.hk

[1]This research project was supported by the Hong Kong Research Grants Council under Grant 744013.

[x]Corresponding author: Professor Peter Kutnick, School of Education Communication & Society, King's College London, Franklin-Wilkins Building, Waterloo Road, London SE1 9NH, email: peter.kutnick@kcl.ac.uk

Attitudes and aspirations regarding engineering among Chinese secondary school students

Abstract

School-based pipelines for university and technical engineering education are recognised as important for economic development and the high-school years are critical for shaping students' career aspirations and attitudes. This study examined a range of attitudes/experiences on the aspirations of secondary students to pursue engineering education and vocation. Predictors covered demographic characteristics, family/school support, practical learning experiences, curricular/extra-curricular experiences, attitudes, perceptions and engineering-efficacy that may affect aspirations. A designed/validated questionnaire capturing these variables was administered to respective samples of secondary school students from four Chinese geo-engineering regions (Beijing, Guangzhou, Hong Kong and ShanXi; 5965 students) that represent differing degrees of industralisation. Comparative analyses across regions show 'doing' engineering is key to motivating students' aspirations; while regional variations suggest that schooling and family factors are generally more significant in industrialising Mainland cities, and extracurricular opportunities and personal factors are more significant for students in post-industrial Hong Kong.

Key words: Engineering education, Secondary schools, Industrialising/post-industrial, China, Attitudes, Efficacy

Introduction

The need to inspire future engineers to enter school-based pipelines that provide inspiration and training for engineers has been acknowledged in industrialising and post-industrial countries (Borrego and Bernhard 2011; Brophy, Klein, Portsmore, and Roger 2008; Katehi, Pearson and Feder 2009; OECD 2010). This study focuses on the secondary school pipeline in China – a country that demonstrates extremes of engineering development. The special administrative of Hong Kong (hereafter HK) has been identified as the most advanced post-industrial society and Mainland China as one of the world's fastest growing industrialising societies (Wei 2005). Both parts of China acknowledge the need to develop students' interest and uptake of careers in engineering (MoE China 2012; HK Education Bureau 2016) and its crucial role in economic development (Xie, Zhang and Lai 2014). Students in both parts of China score at the highest levels in international comparisons of mathematics and science - the bases for engineering (Mullis, Martin, Foy and Arora 2012; OECD 2010). In order to understand how schooling may affect entry into/maintenance of the engineering pipeline, researchers need to develop insight based on students' experiences and opportunities, engagement, motivation, social support and feelings of engineering efficacy (Lucas, Cooper, Ward and Cave 2009). In exploring these effects of schooling and culture, it would be naïve to assume that a single sample can characterise students' experiences, engagement, efficacy, etc. within China – especially as it is known that the Mainland experiences high demand for engineers and high student uptake while HK experiences high demand but has modest student uptake.

Background

Before describing how Chinese schooling may inspire students into the engineering pipeline, we provide a broad consideration of aspects and processes of engineering education in secondary schooling. Internationally, there are few school-provided courses or programmes for the direct study of engineering. In place of engineering, other STM (science, technology, mathematics) subjects are taught throughout junior and senior secondary schools - although engineering experiences have been recommended to take place as early as possible in schooling (Borrego and Bernhard 2011; Capobianco, French and Diefes-Dux 2012; Guzey, Tank, Wang, Roehrig and Moore 2014; Unfried, Faber and Wiebe 2014; Wang and Degol 2013). Schooling contexts may be seen to discourage students' engineering aspirations, for example: the teaching pedagogy underlying engineering and STM courses tends to be formal–theory and teacher-dominated (Lyons 2006). Teachers who present engineering to students often have little background or practical understanding of engineering (Katehi et al. 2009). Few studies actually focus on the impact of school-based engineering education on students (Borrego and Bernhard, 2011; Katehi et al. 2009). Most school-based engineering studies tend to focus on the relationship between teachers' knowledge and students' attitudes to engineering (Lewis, 2007; Nathan, Tran, Atwood, Prevost, and Phelps 2010); although Azjen (1991) notes a poor relationship exists between attitudes and (student) choices for further study/career.

The STEM literature has identified that students are likely to make future education/career choices at earlier rather than later stages of their secondary schooling (Osborne and Archer 2007). Their choices are likely to be affected by actual/authentic experiences (Wang and Degol 2013; Lucas et al. 2009) provided by within-school and extracurricular/out-of-school experiences. Social support is important, whether it comes from parents/close relatives (especially if parent/relative is an engineer; Godwin, Potvin and Hazari 2014) and to a limited extent from peers and teachers (Guzey et al. 2014). A relatively new concept of STEM (including engineering) Capital (from ASPIRES 2013) amalgamates social support with authentic experience within the student's culture and has been associated with positive attitudes and aspirations for future careers. Attempts to draw together theory-based factors allied to students who have become an engineer acknowledge that the STEM (/engineering) "pathway is composed of a series of choices and achievements that commence in childhood and adolescence" and affected by "cultural norms, behaviour, social experiences, aptitudes and affective reactions to previous experience" (Wang and Degol 2013, p.305). Theories of expectancy-value identity (Eccles and Wigfield 2002), social cognitive careers (Lent, Brown, Hackett 1994) and planned behaviour (Ajzen 1991) have all been drawn upon to characterise the choice of engineering study/career. Underlying each of these theories is student engagement in authentic activities and feelings of self-efficacy - considered within the specific domain of engineering (Bandura 1997). In order to compare students' aspirations for engineering-based further study/careers across China, we must be able to draw upon and integrate a diversity of (engineering) information (Wang and Degol 2013) that is likely to include aspects of their demographic background, motivation, perception, experience and efficacy (Lucas et al. 2009).

STEM development in Mainland China

China has been aware of the importance of engineering, science and technology from its earliest days (Zhu and Jesiek 2014). Currently, China is the second largest investor in (engineering-based) research and development (Hong 2015; Oleksiyenko 2014; Liu, Liang and Lui 2012). It has the largest number of and highest proportion (41%) of students studying STEM subjects at the tertiary level (Hong 2015; Zhu 2013). It has an effective pipeline for STEM (Gao 2013). Separate sciences and related STEM topics have been taught in Chinese primary and secondary schools since 1904 (Liu et al. 2012). Its pedagogic approach had been strongly theory-led and teacher dominated until 2000, which is often characterised as based on China's Confucian Heritage [CHC] (Biggs 1996). From 2000, the STEM curriculum was revised to an integrated approach facilitated by an inquiry–based pedagogy. Aspects of technology are integrated into the science curriculum, and school visits provide experience of science applications in society (Wei and Thomas 2007). Curriculum elements have been adapted from the Soviet Union (in the 1950s) and Western countries (from 2000) to support China's pragmatic need for science and engineering (Wan, Wong and Yung 2011; Yu and Hu 2015). All primary and secondary students are required to study science subjects even if they are specialising in arts subjects in upper secondary school (Gao 2013; Wei and Thomas 2007). At the same time, Chinese educators have realised that the range of industrialisation throughout the country requires local and regional applications of science and engineering education. Regions such as ShanXi require engineers oriented towards mining, energy and pottery while Guangzhou requires electrical and electronic engineers (Liu et al. 2012). But, while the literature has identified the need for STEM students (especially engineers) in China, there has been little or no information of how participation in this effective engineering/STEM pipeline affects school-aged students in China and its regions.

STEM education in HK and the Mainland

In Mainland China and HK school attainment is characterised in high stakes testing. Teaching/pedagogic methods were previously characterised by teacher/theory domination and pupil passivity (Biggs 1996), although these methods have been recommended to change towards more pupil involvement via inquiry-based pedagogies (Chow 2011; Liu et al. 2012; Fu and Liu 2016). Students in both regions score at the very highest levels in international testing for science and mathematics (Mullis et al. 2012; OECD 2010). The school systems of HK and the Mainland have developed from distinct educational traditions, although they have many similarities related to STEM education and a CHC background. The importance of engineering for national and regional development has been acknowledged in HK and the

Mainland (HK Education Bureau 2016; MoE China 2012). Mainland China and HK realise that schooling is one of the main forces to promote economic development, and both have developed systems of compulsory primary and secondary education in the latter part of the twentieth century (KPMG 2010). Within compulsory schooling, students are introduced to science, mathematics and technology; engineering is not a formal curriculum topic and rarely offered until upper secondary schooling (and only in some schools).

Comprehensive practical activity courses (*Zonghe shijian huodong kecheng*) have also been required in primary and junior high schools since curriculum reform in the Mainland since 2001. These courses include aspects of engineering education, information/technology, and working skills (MoE China 2001; Zhong 2002). In senior high school, general technology (*Tongyong jishu kecheng*) is compulsory, covering electronic control technology, architecture and design, robot production, modern agricultural technology, housekeeping and life technology, clothing and design, and vehicle driving and maintenance (Ding 2009).

Within HK, there has been greater emphasis on mathematics than science in primary school (Inoue 2013). In the Mainland mathematics and sciences receive equal emphasis (Chow 2011). And, while there is a stated importance in prioritising STEM subjects in HK (HK Education Bureau 2016) aspects of engineering and technology only account for 8% of the secondary school curriculum (Sin 2007). There appears to be a much higher proportion of STEM subjects and curriculum time in the Mainland where over 30% of secondary school credits (towards graduation) are based on STEM subjects (Gao 2013). From this background, it appears that there is greater chance of an effective STEM pipeline in the Mainland than HK. To support the point, we reiterate that 41% of Mainland Bachelor's degrees are in STEM subjects (Hong 2015). While there is no comparable figure for HK, we note that 15% of the 2015 entries for Bachelor's degrees in HK universities were for the study of engineering/applied engineering (JUPAS 2015) and this represents a continuing decline in the number/proportion of HK students applying to study engineering over recent years (JUPAS 2013).

In summary, the literature has identified similarities and differences with regard to those choosing to study engineering/STEM subjects at tertiary level across the various regions of China. In particular, both HK and the Mainland have espoused the need for engineers in the promotion of economic development of their regions and have identified the school system as the main vehicle to introduce potential engineering aspirations to its students. Yet, there are distinct differences in effectiveness of the school-based pipeline for introducing (future) engineers to higher education between industrialising and post-industrial regions of China. Understanding why these differences exist may be attributed to limited distinctions between school systems but is more likely to be found in the effects of schooling and culture on secondary school students. Currently, there is a dearth of studies of attitudes, understanding of and interest in engineering among school-aged students in China. Using a focused survey and selecting distinct geo-engineering regions of China, this study draws upon student demographic information, their engineering experience (curricular and extra-curricular), perception of engineers, engineering efficacy and aspirations to become an engineer as it seeks to:

1. Identify engineering-based experiential, attitudinal, perceptual, efficacy and aspirational differences between post-industrial HK and the industrialising Mainland;
2. Identify engineering-based experiential, attitudinal, perceptual, efficacy and aspirational differences between geo-engineering regions within the Mainland – especially with regard to ShanXi (known for mining and pottery), Guangzhou (known for its electronic engineering) and Beijing (known for light, civil and general engineering); and
3. Draw insight from the survey regarding effects of geo-engineering regions and schooling regarding secondary school students' aspirations to become an engineer.

Methods

Sample

Within China: Three separate geo-engineering regions were sampled to provide a range of secondary school types in Guangzhou, Beijing, and ShanXi. Sampling was undertaken on a form-within-school basis. 2241 questionnaires were distributed/collected: Guangzhou, 406 questionnaires (male: 186; female: 220); Beijing, 1153 questionnaires (male: 662; female: 462); ShanXi, 681 questionnaires (male: 318; female: 353). Data was also collected regarding year of study (three groups: Forms 1/2: 622 students; Forms 3/4: 1315 students; and Forms 5/6: 301 students); type of school attended (Beijing and ShanXi: Grammar: 1494; Vocational: 340; Guangzhou: Grammar: 407); and ethnic background of students (95+% self-identified as Han). Given the homogeneity of this part of the sample, ethnicity was not used to differentiate between student responses (see Table 1).

TABLE 1 ABOUT HERE

HK: This sample was representative of government-funded secondary schools. It was proportionally stratified (age and sex of student, school type and district) with a randomized selection of schools and classes within each selected school. The sample included 3,724 students (male: 1648; female: 2032; 44 unreported).

Each school principal and participant signed a consent form to indicate their active agreement to participate in the study. Parents of each student also provided consent.

Instrument

The survey questionnaire was adapted from the Education and High Growth Innovation project (EHGI, Good and Greenwald 2007) to focus on secondary school students' engineering education experience and aspirations to study/pursue a career in engineering. The questionnaire covers student demographics, curricular and extra-curricular engineering experience, (activity-based) learning experiences and engineering efficacy (see Table 2). Question groupings were assessed by tick boxes, frequencies, Likert and competence scales. The adapted questionnaire was originally validated (face and content) in Hong Kong (in both English and Traditional Chinese) with the Chinese version back-translated. The Chinese version was further validated in a (Guangzhou) pilot study and used in Beijing and ShanXi regions.

Data management

An Exploratory Factor Analysis (EFA) was conducted on the Guangzhou pilot sample to examine the underlying factor structure, identify and differentiate between individual questions, ascertain whether item groups or an underlying singular engineering factor characterized the questionnaire and assess for reliability of factors (Worthington and Whittaker 2006). The EFA produced a Kaiser-Meyer-Olkin (KMO) of 0.890 (showing sampling adequacy for analysis) and Bartlett's Test for Sphericity (X^2[5671] = 22724.91, $p<0.001$ - showing that the data were appropriate for factor analysis). The EFA used Varimax factor rotation with a minimum eigenvalue of 1.0 and showed a large number of factors related to the nine, logic-based item-groups. With regard to each item grouping, reliability was established via "alpha-if-item-deleted" tests to ensure that only key contributing questions (with a factor loading of 0.50 or above) were included in each item-group/factor. Reliability averaged for the nine item-groups was 0.83 (ranging from 0.63 to 0.95). Each factor and sub-factor reached satisfactory levels of reliability (McMillan and Schumacher 2001), with the exception of parental encouragement – which was marginally below the 0.70 limit of reliability. After the EFA, reliability of the factors were assessed on the non-pilot China sample (1795 questionnaires); with an average item group reliability of 0.84 (range: 0.67 to 0.95). Two further reliability assessments were undertaken, one combining the pilot with the other Chinese geo-engineering regions (2201 questionnaires) and the other combining all Chinese regions with Hong Kong (5925 questionnaires). Average reliability for all Chinese regions was 0.86 (range 0.66 to 0.95) and the combination of China with Hong Kong was 0.85 (range 0.64 to 0.95).

TABLE 2 ABOUT HERE

Item-groups (factors and sub-factors) were divided into Outcome and Predictor factors. Outcome expressed the aspiration become an engineer. Eight Predictor factors with four Sub-factors were structured from questionnaire groupings concerning engineering-oriented attitudes, motivations, activities and perceptions of engineers. Once factors were established, descriptive statistics provided means and correlations between factors. Further analyses compared between regions supported by Scheffe post hoc analyses to ascertain significance of difference between regions. To ascertain relative contribution of the various factors to the outcome hierarchical regressions were undertaken in HK, the Mainland and within Mainland regions. While the use of regression as a method in social statistics has been looked upon critically (Whittingham, Stephens, Bradbury and Freckleton 2006), it is a technique that has proved useful in allowing us to prioritise types of causal explanations associated with aspirations to become an engineer. Ordering of regression variables initially partialled out demographic from attitudinal/experiential variables, and variable hierarchy was based on a combination of literature and magnitude of means identified in our descriptive results. Tests for collinearlity (VIF) showed moderate to low levels within these regressions.

Results

Summary explanations of factors (see Table 3):

1. Practical (learning) activities related to STEM subjects: The factor's moderately high mean indicates these aspects were important for students, and included: 'I enjoy hands on activities'; 'I enjoy working in a team with other students'; and 'I enjoy doing experiments in science'. A sub-factor based on what engineers do and having a background in science and mathematics had a mid-level mean.

2. Participation in engineering related activities at school: The mean indicates that students rarely participated in these activities. Nearly half of the students (47%) did not participate in any within-school engineering activities), while a few students were very active (19%) participated in 5 or more activities.

3. Encouragement to participate by STEM teachers: The factor's moderately high mean indicates that these teachers encouraged students to do well in their STEM subjects. Of the three types of STEM teachers, students noted that mathematics teachers were most encouraging; science and D/T teachers were rated as neutral or slightly discouraging.

4. Encouragement to participate in STEM activities by parents: The mean indicates moderately high encouragement. Students were more inclined to note 'My parents/guardians think education is important' than providing specific support for science-based study and career.

5. Extracurricular engineering activities: The moderately low mean indicates infrequent engagement in these activities (clubs, meeting engineers, etc.). Students were more likely to engage in home-based, hands-on activities ('Built something from a kit', 'Fixed something at home that was broken', 'Taken something apart to see how it works'. This hands-on engagement formed the basis of the Build/take apart/explain (BTE) sub-factor.

6. Motivation to engage in school-based engineering activities: The moderate mean suggests that students did not receive much stimulation in this range of activities. A sub-factor composed of 'My friends go' and 'My teacher encourages me to go' was identified with a mid-level mean.

7. Perceptions of engineers/engineering: The relatively high mean indicates a strong positive view of engineers; the most outstanding features of these perceptions were: 'Creative', 'Could fix and mend things', 'Is a problem solver', 'Has a positive effect on people's lives', and 'Is good at maths and science' (4.64). Perceptions also showed that engineers were unlikely to be women or come from an ethnic minority. A Presentation of engineers sub-factor was also found ('Works in an office' or 'Wears a boiler suit') was found with a mid-level mean.

8. Engineering efficacy: Given efficacy/confidence could range from 0 to 100%, the mean indicates only a moderate level of confidence in undertaking these tasks. The highest item averages indicated strong elements of social confidence ('Get another student to help me when I am stuck' [68.82], 'Get a teacher to help me with I am stuck with my work' [68.80], 'Help another student who is stuck' [67.49], 'Get other people to understand what I want them to do' [65.47]), specific aspects of learning ('Learn how to use new computer software' [66.71], 'Learn a foreign language' [65.71], 'Learn geometry' [65.58], 'Learn algebra' [64.65]), and explain ('Why we recycle paper' [66.63]). Learning of mathematics subjects (algebra and geometry) formed an identifiable sub-factor with a mean of 63.05.

9. The outcome factor was composed of two items ('I really want to be an engineer' and 'I want to know more about engineering'): The mid-level mean indicated that, generally, students were not very interested/nor expected to become an engineer.

TABLE 3 ABOUT HERE

Table 4 displays significant and consistent Pearson product-moment correlations within Predictor factors and between the predictor factors and the outcome factor. Generally, students had a positive engineering focus throughout and identified: a) strong correlations between the Outcome factor and Motivation, Practical activities and Extracurricular (engineering) activities; b) Adult encouragement had a consistent and strong effect on other factors; c) Engineering efficacy was a strongly related to most factors; but d) School-based engineering activity had the lowest level of correlation related to all other factors.

TABLE 4 ABOUT HERE

Mainland demographic differences

Four main demographic variables were assessed for differences with regard to each of the predictor and outcome variable (see Table 5):

Relative as engineer results show consistent attitudes, experiences and efficacy that favoured students with engineering relatives. All predictor factors were significantly higher for students with engineering relatives – except for Engineering activities in school. These differences were also consistent for sub-factors Knowledge about engineering, BTE and Mathematics efficacy. Students with engineering relatives were more likely to Aspire to become an engineer.

Age results show limited consistency but may point to periods in students' lives when aspects of engineering were most important. The youngest age group scored at the highest levels of Encouragement by teacher, Engineering efficacy and Mathematics efficacy. The mid-age group was the most involved in Engineering activities in school, Encouragement by parent and Extracurricular involvement. The oldest age group scored highest for BTE sub-factor, Motivation to engage in engineering activities, Perception of engineers and Aspiration to become an engineer, but had the lowest levels of involvement in within-school Engineering activities and engineering Motivation. There were no significant age differences for Practical (learning) activities or its sub-factor. Efficacy and Encouragement by teacher were highest with the youngest students.

Sex results show males more likely to participate in engineering activities than girls with regard to: Practical (learning) activities, Knowledge about engineering, Extracurricular engineering activities, BTE, Motivation to engage in engineering activities and Outcome (Aspiration to become an engineer). With the exception of Practical (learning) activities, none of the means were high. There were no statistically significant differences with regard to Engineering activities in school, Encouragement by teacher, Encouragement by parents, Perception of engineers and, most strikingly, General engineering efficacy and the Mathematics efficacy sub-factor.

School type results showed consistently high levels of attitude and efficacy – all of these results favoured students attending grammar school as opposed to vocational school (analysis undertaken for Beijing and ShanXi only). Grammar school students had higher predictor factors for: Practical (learning) activities, Knowledge about engineering sub-factor, Motivation to engage in engineering activities; Encouragement by teacher and parent; and Engineering efficacy. There was only a small difference between schools for Engineering activities in school, and no difference for Extracurricular engineering activities (also BTE sub-factor) or the Aspiration to become an engineer.

TABLE 5 ABOUT HERE

Given that both demographic and attitudinal/experiential factors appeared to affect students' aspirations (to become an engineer), hierarchical linear regressions were undertaken to prioritise which factors contribute significant variance regarding students' aspirational decisions (Table 6a). With demographic factors initially partialled out, 44.1% of variance was contributed by attitudinal/experiential factors. Only a further 4.1% of variance was contributed by demographic actors. Table 6a identifies that initial demographic factors of an Engineer in the family, Age of student and Sex were each significant. The combined demographic and attitudinal/experiential only found significance for Age and a hierarchy of: Motivation to engage in engineering activities, Practical learning activities, Encouragement by teacher, Extracurricular engineering activities and Engineering activities in school. Encouragement by parents, Perceptions of engineers and Engineering efficacy did not offer significant contributions of variance to student Aspirations.

TABLE 6 ABOUT HERE

Differences between the Mainland and HK

While the Mainland and HK share common statehood in an engineering/economic sense, China is described as an industrialising country while HK is a highly advanced post-industrial society. Both societies and their education systems have been described as CHCs (Biggs

1996). In our comparisons Mainland students had higher scores for virtually of the Predictor and Outcome factors (see Table 3). With regard to the particular factors:

1. Practical (learning) activities were more highly rated in the Mainland (than HK) and this characterised each of the individual questions. Mainland students also showed greater Knowledge about engineering (sub-factor).
2. Participation in engineering related activities at school showed higher levels of engagement in the Mainland than HK. Differences were particularly identified in 'Visit educational websites related to engineering', 'Participate in competitions related to engineering or computers', and 'Participate in engineering or computer societies in school'.
3. Encouragement by teachers did not show significant differences between the Mainland and HK, although within the individual questions Mainland mathematics teachers were identified to be more encouraging.
4. Encouragement by parents was significantly stronger in the Mainland, and this was consistent for each of the individual questions.
5. Extracurricular engineering activities did not show high levels of engagement in either Mainland or HK, but Mainland students were significantly more likely to be engaged in these activities. These differences were more emphatic within the BTE sub-factor and its component questions.
6. Motivation to engage in school-based engineering activities was significantly higher in the Mainland. The Social motivation sub-factor was also rated higher in Mainland, and this finding was supported by Teacher encouragement. There were no peer-support differences between Mainland and HK.
7. Perceptions of engineers/engineering were rated significantly higher in Mainland. This rating was found in most of the individual questions, with the exception of 'Has a degree', 'Is female' and 'Comes from an ethnic minority'. There was no significant difference in the Presentation of engineers sub-factor.
8. Engineering efficacy showed Mainland students to feel significantly more confident in engineering activities generally (by an average of 5%), and with regard to each of the individual questions (with the exception of 'Organise a team to build a bridge'). Learning of mathematics sub-factor was also significantly higher for Chinese students.
9. The outcome factor was rated significantly higher for Mainland students

Given the consistent factor differences between Mainland and HK, a separate hierarchical regression was undertaken for HK so that contributory factors to students' aspirations could be compared with the Mainland (Table 6b). This regression initially partialled-out demographic factors. Attitudinal/experiential factors contributed 45.6% of variance to student aspirations and demographic factors contributed a further 4.8%. In HK, the demographic analysis identified Sex (males) of student, Engineer in the family and Age each contributed significantly. The combined demographic and attitude/experience factors only reinforced Sex and Age of students with a hierarchical order of variance dominated by: Motivation to engage in engineering activities (similar to the Mainland); Extracurricular engineering activities; Practical learning activities; Perception of engineers; negative variance for Encouragement by teacher; and Engineering efficacy. HK did not identify within-school engineering activities or Encouragement by parent as making a significant contribution to student Aspirations. In both regions, the demographic factor of Age made a significant contribution, but only in HK did sex (males in particular) make a further significant contribution.

TABLE 7 ABOUT HERE

Differences between regions within Mainland China

The Mainland sample included three different geo-engineering regions: Beijing, ShanXi, and Guangzhou. Differences between these regions may be associated with diverse experiential and cultural backgrounds. As presented in Table 3, differences between regions identify that students in Beijing had generally higher scores than the other regions although Guangzhou had the highest Outcome score. More specifically, students in all regions had similar engagement in Practical (learning) activities; this non-significant difference hides the more specific finding that Beijing had the highest individual question scores except for 'I want to do engineering subjects after secondary school' where Guangzhou students scored highest. Students in Guangzhou had the highest amount of Engineering activities in school and ShanXi students had the least. Students identified that Guangzhou teachers provided the highest levels of Encouragement with ShanXi providing the lowest levels; this was consistent among all types of teacher (science, mathematics, D/T). Encouragement by parent was strongest in Beijing and weakest in ShanXi; although all parents provided strong support for their children's education. Beijing provided the strongest encouragement for science education and Guangzhou parents provided the strongest encouragement for engineering education. Beijing students were more engaged in extracurricular engineering activities. The greater extracurricular involvement by Beijing students was particularly seen in the BTE sub-factor. Guangzhou students had slightly higher Motivation to engage in engineering levels than Beijing or ShanXi students – with Guangzhou students showing more engagement in curiosity about what engineers do and how they do it. Beijing students showed higher Social motivation (sub-factor) with their scores encouraged by peers and teachers. All students, though, maintained neutral feelings with regard to 'It will help me do well in my exams'.

Guangzhou students had a more positive Perception of engineers than other regions, and this characterised most of the individual questions. ShanXi students, though, had higher levels of perception that engineers worked in offices and wore suits (Work conditions sub-factor). Beijing students showed the highest level of General engineering efficacy and this characterised most of the individual questions. Beijing students also scored highest on the Mathematics efficacy sub-factor as well as individual questions concerned with working with others (similar to the Social motivation sub-factor finding). An explanation of differences between Predictor factor findings among the Chinese regions appears to tell two stories: 1) that Beijing students generally had more access to practical, extracurricular and social activities related to engineering as well as parental encouragement and these experiences may have promoted their higher level of engineering efficacy; but 2) Guangzhou students had more access to engineering activities in school and encouragement by teachers, and this was associated with higher perceptions of engineers and motivation to engage in engineering activities. The Outcome factor results shows that the Guangzhou students had slightly higher Aspirations to become an engineer than Beijing students and both of these regions had significantly higher Aspirations than students in ShanXi.

Discussion of results

The need to maintain and further develop the engineering pipeline from secondary school to university and technical careers has been recognised universally if a country is to develop in the twenty-first century (Borrego and Bernhard 2011; King 2008; RAEng 2013; Sohn and Ju 2010). Within this recognition it is important to focus on secondary school students, as they represent the age group in which engineering experiences are likely to affect their aspirations for further study/careers in engineering and associated STEM subjects (Osborne and Archer 2007). Yet, simply asking secondary school students whether they wish to pursue studies and careers in engineering provides little insight into elements of the engineering pipeline. Recent studies have identified the importance of authentic experiences, attitudes, perceptions and efficacy that may affect the aspiration to become an engineer (Borrego and Bernhard 2011; Katehi et al. 2009; Lucas et al. 2009). We recognise that engineering aspirations may be affected by these aspects of culture, but note there are few comparisons between cultures aside from industrialising and post-industrial differences (Wei 2005). We have focused on China and compared between geo-engineering regions that represent differences between post-industrial and industrialising regions that require engineering foci on mining, electronics and general engineering. Results advance our knowledge of the engineering pipeline in the various regions of China. In comparing between geo-engineering regions, we provide insight into effects across the secondary school age range and diverse aspects of students' attitudes, authentic experiences, perceptions and efficacy with regard to engineering and student aspiration for the further study of/careers in engineering.

Focusing initially on demographic explanations for Mainland students, results partially confirm findings in the international literature. Sex differences showed boys had higher levels of knowledge and more positive attitudes regarding engineering, and this parallels the international literature (Borrego and Bernhard 2011; Brophy et al. 2008; Unfried et al. 2014). But, a lack of sex differences regarding engineering efficacy, encouragement from teachers/parents/peers, perceptions of engineers and within-school engineering activities (also seen in the regression analyses) may indicate that the Mainland's approach to the curriculum integrates mathematics, science and technology courses for all students (even if the students have an arts bias; Gao 2013; Wei and Thomas 2007). Age differences in attitudes and experiences supported the international literature showing that younger students had more positive attitudes and career aspirations regarding engineering (Capobianco et al. 2012; Wang and Degol 2013). Yet, students in the middle years of secondary schooling were offered/took-up more engineering activities and received more encouragement/support from their teachers. Effects of these enhanced engineering experiences may be seen to affect more positive perceptions and attitudes towards engineers as well as aspirations to become an engineer among the oldest students – contradicting the international literature (Osborne and Archer 2007). Type of school attended affected all aspects of attitudes, experiences, efficacy and aspirations regarding engineers and engineering. Across the Mainland, it was the grammar as opposed to vocational schools that had the most positive views of engineers – this finding may contradict the expectation that vocational schools should provide focused STEM experiences for students (Watters and Christensen 2013). Finally, students with close relatives who work as an engineer had more positive attitudes, experiences, higher perceptions and efficacy regarding engineering (ASPIRES 2013; Devine 2004). From this initial review, we speculate that aspects of home, school type and gender may combine into an Engineering Capital that supports the aspiration for further study/careers in engineering.

Industrialising/post-industrial differences showed Mainland students to have more positive views of engineers than HK students. This difference bears strong resemblance to the international literature (Wei 2005) although we acknowledge that industrialising/post-industrial differences can be found within a single country also. Comparisons showed that motivation to engage in engineering provided most of the variance in students' aspiration to become an engineer in both regions. The role of parents was important for Mainland students, as identified in the international literature (ETB 2005; Godwin et al. 2014) and in descriptions of Chinese CHC (Biggs 1996). Parents contributed very little to HK student's aspirations – suggesting that CHC may be related to specific sub-cultures within Chinese society. HK students had a stronger reliance of facilities provided around the school (extracurricular clubs, practical learning activities) than their Mainland counterparts – perhaps identifying differences between the range of engineering experiences and Engineering capital that can be offered within schools (Borrego and Bernhard 2011) in this post-industrial society. The role of engineering efficacy was significantly higher in the Mainland than HK, although this did not contribute a significant amount of variance to the aspiration to become an engineer in the Mainland. These comparisons begin to identify regional cultural differences: Engineering/STEM culture appears to have a stronger collective basis in schooling and parental support in the Mainland, while HK students are dependent on involvement in extracurricular activities, personal perceptions of engineers and engineering efficacy.

Mainland comparisons show geo-engineering regional differences that relate to types of engineering that characterise regions and advancement towards post-industrialisation. Given that all Mainland schools provide a strong science, mathematics and technology background for students, it was not surprising to see high levels of practical (hands-on) learning activities taking place in all regions. Beijing and Guangzhou offered higher levels of extracurricular engineering activities and within school engineering activities than ShanXi. There were also higher levels of parental support in Beijing and Guangzhou than ShanXi - suggesting lower levels of industrialisation and exposure to a broad range of modern engineering activities in ShanXi. Differences between Beijing and Guangzhou were found with regard to school and home. Guangzhou students received the highest levels of teacher encouragement, within-school engineering activities and had more positive perceptions of engineers, attitudes towards engineering, and aspirations to become an engineer. Beijing students, with higher levels of parental support and extracurricular engineering activities, appeared to have more (non-school based) engineering opportunities and this was associated with a higher level of engineering efficacy.

The differences found between these regions offer the opportunity to identify a range of new explanations for the perception and understanding of engineering within a large industrialising country. An initial explanation for geo-engineering differences within the Mainland identifies a trend that runs counter to the international (post-industrial) literature – that suggests lower levels of interest in engineering as a country becomes more industrialised (Wei 2005). It appears from our data that the more advanced industrial regions (moving away from heavy/mining engineering towards electronic and civil engineering) offer more engineering activity opportunities within and outside of schools. These opportunities are associated with more positive student perceptions of engineering and higher levels of aspiration to become an engineer. It seems obvious that schools and schooling processes play a strong role in offering insight and support for the future development of engineers (suggested by Borrego and Bernhard 2011; Katehi et al. 2009) – especially where teachers and within-school engineering activities provide support and encouragement for students as found in the Guangzhou region. Both opportunities offered and encouragement provided support the need to develop a more sophisticated notion of Engineering/STEM Capital (ASPIRES 2013). Engineering/STEM capital, which appeared higher in both Beijing and Guangzhou than ShanXi, is likely to include elements of practical learning activities, motivation to engage in engineering opportunities, encouragement by parents and teacher, extracurricular opportunities and feelings of efficacy. These elements parallel science capital with regard to students' development of positive attitudes (and perceptions) of engineers, supported by family (where a close relative is an engineer) and teachers, and participation in extracurricular contexts. It should be noted, though, within-school engineering opportunities appear to play a limited role in the development of Engineering/STEM capital – this may be explained by the infrequent inclusion of engineering within the formal curriculum and, perhaps, limited understanding of engineering by teachers (Holman 2007).

References

Ajzen, I. 1991. “The theory of planned behaviour.” *Organizational behavior and human decision processes* 50 (2): 179-211.

ASPIRES. 2013. *Young people’s science & career aspiration, age 10-14.* London: Department of Education and Professional Studies, King’s College London.

Bandura, A. 1997. “Personal efficacy in psychobiologic functioning.” In *Bandura: A leader in psychology*, edited by G. V. Caprara, 43-66. Milan, Italy: Franco Angeli.

Biggs, J. 1996. “Western misconceptions of the Confucian-heritage learning culture”. In *The Chinese learner: Cultural, psychological and contextual influence*, edited by D.Watkins and J.Biggs, 45-67. Hong Kong: CERC and ACER.

Borrego, M., and Bernhard, J. 2011. “The emergence of engineering education research as an internationally connected field of inquiry.” *Journal of Engineering Education* 100 (1): 14-47.

Brophy, S., Klein, S., Portsmore, M., and Rogers, C. 2008. “Advancing engineering education in P‐12 classrooms.” *Journal of Engineering Education* 97 (3): 369-387.

Capobianco, B.M., French, B.F., and Diefes-Dux, H.A. 2012. “Engineering identity development among pre-adolescent learners.” *Journal of Engineering Education* 101 (4): 698-716.

Chow, C.M. 2011. “Learning from our global competitors: A comparative analysis of science, technology, engineering and mathematics (STEM) education pipelines in the United States, Mainland China and Taiwan.” EdD diss., University of Southern California.

Devine, F. 2004. *Class practices: How parents help their children get good jobs*. Cambridge: Cambridge University Press.

Ding, H. (2009). “Learning from technology training for vocational education and designing the instruction of general technology course for senior high schools (in Chinese).” *Theory and Practice of Education* 7: 12-14.

Eccles, J., and Wigfield, A. 2002. “Motivational beliefs, values and goals.” *Annual Review of Psychology* 53: 109-132.

Engineering and Technology Board (ETB). 2005. *Factors Influencing Year 9 Career Choices*. London: ETB.

Fu, Q. and Liu, P. 2016. “From verification to creation: A research on STEM education performance models in middle and primary schools.” *China Audio-visual Education* (4): 71-78+105.

Gao, Y. 2013. *Report on China’s STEM education*. Accessed 15 June 2016. http://www.acola.org.au/PDF/SAF02Consultants/Consultant%20Report%20-%20China.pdf

Godwin, A., Potvin, G. and Hazari, Z. 2014. “Do engineers beget engineers? Exploring connections between engineering-related career choices of students and their families.” Paper presented at the annual meeting for the American Society for Engineering Education, Indianapolis, IN, June 15-18.

Good, D., and Greenwald, S. eds. 2007. *University Collaboration for Innovation: Cambridge MIT Institute.* Rotterdam: Sense.

Guzey, S.S., Tank, K., Wang, H.H., Roehrig, G., and Moore, T. 2014. “A High-Quality Professional Development for Teachers of Grades 3–6 for Implementing Engineering into Classrooms.” *School Science and Mathematics* 114 (3): 139-149.

Holman, J. 2007. *Improving Guidance on STEM Subject Choice and Careers*. York: DFES School Science Board.

Hong Kong Education Bureau. 2016. *Education Bureau promotes STEM education to nurture students' innovative thinking*. Accessed 15 June 2016. http://www.info.gov.hk/gia/general/201601/22/P201601210388_print.htm

Hong, Y. 2015. “Engineering education in China.” Paper presented at the International Conference on Interactive Collaborative Learning, Florence, September 20-24.

Inoue, Y. 2013. “Secondary education in Hong Kong.” World Education News & Reviews. Accessed 12 December 2015. http://www.wenr.wes.org/2013/01/wenr-januaryfebruary-2013-hong-kong-secondary-education.

Joint University Programmes Admissions System (JUPAS). 2013. “JUPAS Admissions Scores of Participating-institutions 2013.” Accessed 20 June 2016. http://www.jupas.edu.hk/upload/useful_material/af_2013.pdf

Joint University Programmes Admissions System (JUPAS). 2015. Listing of admission number to Hong Kong Universities for the study of engineering subjects. Personal communication.

Katehi, L., Pearson, G., and Feder, M. 2009. *Engineering in K-12 Education: Understanding the Status and Improving the Prospects.* Washington, DC: The National Academies Press.

King, R. 2008. *Addressing the Supply and Quality of Engineering Graduates for the New Century*. Sydney: Carrick Institute.

KPMG. 2010. *Education in China*. Hong Kong: KPMG. Accessed 5 August 2016. http://kpmg.de/docs/Education-in-China-201011.pdf.

Lent, R. W., Brown, S. D., and Hackett, G. 1994. “Toward a unifying Social Cognitive Theory of career and academic interest, choice, and performance.” *Journal of Vocational Behavior* 45 (1): 79-122.

Lewis, T. 2007. “Engineering education in schools.” *International Journal of Technology and Design Education* 25 (5): 843-852.

Liu, X., Liang, L.L., and Liu, E. 2012). “Science Education Research in China: Challenges and Promises.” *International Journal of Science Education* 34 (13): 1961-1970.

Lucas, W.A., Cooper, S.Y., Ward, T., and Cave, F. 2009. “Industry placement, authentic experience and the development of venturing and technology self-efficacy.” *Technovation* 29 (11): 738-752.

Lyons, T. 2006. “Different countries, same science classes: Students’ experiences of school science in their own words.” *International Journal of Science Education* 28 (6): 591-613

McMillan, J.H., and Schumacher, S. 2001. *Research in education: A conceptual introduction* (5th ed.). New York: Longman.

Ministry of Education, People's Republic of China (MoE China). 2001. *Outline of Basic Educational Curriculum Reform (Trial) (in Chinese)*. Accessed 2 October 2016. http://www.moe.edu.cn/publicfiles/business/htmlfiles/moe/moe_309/200412/4672.html

—— 2012. *On the Establishment of National Practical Engineering Education Centers (in Chinese).* Accessed 15 June 2016. http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/A08_zcwj/201207/139258.html

Mullis, I.V.S., Martin, M.O., Foy, P., and Arora, A. 2012. *TIMSS 2011 International results in Mathematics.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Nathan, M.J., Tran, N.A., Atwood A., Prevost, A. and Phelps, L. A. 2010. “Beliefs and expectations about engineering preparation exhibited by high school STEM teachers.” *Journal of Engineering Education* 99 (4): 409-426.

Oleksiyenko, A. 2014. “On the shoulders of giants? Global science, resource asymmetries, and repositioning of research universities in China and Russia.” *Comparative Education Review* 58 (3): 482-508.

Organization for Economic Co-operation and Development (OECD). 2010. *PISA 2009 Results: What students know and can do – Student performance in reading, mathematics and science (Volume I)*. Paris: OECD.

Osborne, J., and Archer. L. 2007. *Science Careers and Aspirations: Age 10-14.* Economic and Social Research Council (ESRC) Funded Research Project.

The Royal Academy of Engineering (RAEng). 2013. *Enhancing STEM education in secondary schools*. London: Royal Academy of Engineering. Accessed 5 December 2015. http://www.raeng.org.uk/publications/other/book-final-web

Sin, T. W. 2007. *Technology Education: A Smart Choice for both Career and Further Studies (in Chinese)*. Accessed 20 July 2011. http://www.hkedcity.net/article/teacher_law334/070820-001.

Sohn, S. Y., and Ju, Y. H. 2010. “Perceptions of engineering among Korean youth.” *International Journal of Engineering Education* 26 (1): 205-217.

Unfried, A., Faber, M., and Wiebe, E. 2014. “Gender and student attitudes toward science, technology, engineering and mathematics.” Paper presented at American Educational Research Association Annual Conference, Philadelphia, PA. April 3-7.

Wan, Z., Wong, S., and Yung, B. 2011. “Common interest, common visions? Chinese science teacher educators' views about the values of teaching nature of science to prospective science teachers.” *Science Studies and Science Education* 95 (6): 1101-1123.

Wang, M-T., and Degol, J. 2013. “Motivational pathways to STEM career choices: Using expectancy-value perspective to understand individual and gender differences.” *Developmental Review* 33: 304-340.

Watters, J.J., and Christensen, C. 2013. “Vocational education in science, technology, engineering and maths (STEM).” Paper presented at European Science Education Research Association annual conference, Nicosia, Cyprus, September 2-7.

Wei, B., and Thomas, G. P. 2007. “The post-Mao junior secondary school chemistry curriculum in the people’s republic of China: A case study in the internationalization of science education.” In *Internationalisation and globalisation in Mathematics and Science Education*, edited by B. Atweh, B., Barton, A.C., Borba, M.C., Gough, N., Keitel and Vistro-Yu, C. 487-507. Dordrecht, Netherlands: Springer.

Wei, J. 2005. “Engineering education for a post-industrial world.” *Technology in Society* 27: 123-132.

Whittingham, M.J., Stephens, P.A., Bradbury, R.B., and Freckleton, R.P. 2006. “Why do we still use stepwise modelling in ecology and behaviour?” *Journal of Animal Ecology* 75 (5): 1182-1189.

Worthington, R., and Whittaker, T. 2006. “Scale development research: A content analysis and recommendations for best practices.” *Counseling Psychologist* 34: 806-838.

Xie, Y., Zhang, C., and Lai, Q. 2014. “China's rise as a major contributor to science and technology.” *Proceedings of the National Academy of Sciences of the United States* 111 (26): 9437.

Yu, S. and Hu, X. 2015. “STEM Education and its Model for Interdisciplinary Integration (in Chinese).” *Open Education Research* 21(4): 13-22.

Zhong, Q. 2002. “Comprehensive Practical Activity Course: Connotation, Value, and Misunderstanding (in Chinese).” *Education Research* 2: 42-48.

Zhu, Q., and Jesiek, B. K. 2014. “In pursuit of the Dao in policymaking: Toward a cultural approach to understanding engineering education policy in China.” *Technology in Society* 38: 169-176.

Zhu, G. 2013. “The Status and Prospects of Engineering Education in China.” Paper presented at the Council for Academies of Engineering and Technological Sciences, Budapest, Hungary, June 27.

Table 1: Breakdown of China sample and geo-engineering region sub-samples, based on demographic characteristics

Characteristics	*N* (questionnaires completed)	% (of Mainland sample)
REGION		
Beijing	1153	51.5
ShanXi	681	30.4
Guangzhou	407	18.2
INDIVIDUAL		
Sex:		
Male	1166	52.0
Female	1035	46.2
Unreported	40	1.8
Age		
12-13	622	27.8
14-15	1315	58.7
16-18	301	13.4
Unreported	3	0.1
SOCIAL		
Relative as engineer		
Father	174	7.8
Mother	54	2.4
Other close relative	471	21.0
Unreported or don't know	1542	68.8
CULTURAL		
Ethnicity		
Chinese - Han	2150	95.9
Chinese – Zhuang	2	0.1
Chinese – Manchu	39	1.7
Chinese – Hui	24	1.1
Chinese – Mongol	7	0.3
Chinese – Other	10	0.4

Non-Chinese – Other	1	0.0
SCHOOL*		
Type:		
Grammar	1494	66.7
Vocational	340	15.2
Unreported	407	18.2

* Data was only collected on this characteristic for Beijing and ShanXi

Table 2: Item–groups for Predictor and Outcome factors with descriptions and measures of reliability (*italics indicate sub-factors related to main group factors*): measurement, Exploratory Factor Analyses and Confirmation of Reliability

Predictor factors with question examples	How measured	EFA			Reliability across samples		
		Post "alpha-if-item-deleted" questions included	Eigenvalue (Proportion of variance)	Cronbach α	Sample w/o pilot Cronbach α	Sample with pilot Cronbach α	Include HK Cronbach α
Practical (learning) activities related to STEM subjects Ex: I enjoy learning; I enjoy taking things apart to see how they work	6-pt scales (strongly agree – strongly disagree)	10 questions	4.71 (31.36)	0.85	0.86	0.86	0.88
Sub-factor: Knowledge about engineering sub-factor *Ex: I understand what engineers do in industry; I understand how engineers use maths and science*		*2 questions*	*1.70 (11.36)*	*0.82*	*0.84*	*0.84*	*0.83*
Participation in engineering related activities at school Ex: Attend seminars conducted by engineers; Participate in competitions related to engineering	2-pt scales (participation – non-participation	6 questions	2.16 (35.97)	0.63	0.70	0.90	0.88
Encouragement to participate by STEM teachers Ex: My science teacher encourages me to do well; My D&T teacher encourages me to do well	6-pt scales (strongly agree – strongly disagree)	3 questions	2.33 (58.24)	0.85	0.82	0.82	0.64

Encouragement to participate in STEM activities by parents Ex: My parents know a lot about science; My parents think engineering is a good career	6-pt scales (strongly agree – strongly disagree)	4 questions	2.14 (42.86)	0.67	0.66	0.66	0.70
Extracurricular engineering activities Ex: Attend engineering club at school; Fixed something that was broken at home	6-pt scales (participate very frequently – no participation)	19 questions	10.62 (53.10)	0.95	0.95	0.95	0.95
Sub-factor: BTE (Build/Take apart/Explain) sub-factor *Ex: Explained how something I built works; Taken something apart to see how it works*		*4 questions*	*1.90 (9.48)*	*0.95*	*0.84*	*0.83*	*0.84*
Motivation to engage in school-based engineering activities Ex: I like making things; I like to experiment with things	6-pt scales (strongly agree – strongly disagree)	7 questions	4.63 (38.57)	0.86	0.86	0.86	0.88
Sub-factor: Social encouragement		*2 questions*	*1.56 (12.99)*	*0.72*	*0.74*	*0.74*	*0.71*
Perceptions of engineers/engineering Ex: Creative; Is an original thinker; Can help solve environmental problems	6-pt scales (very likely – very unlikely)	16 questions	7.07 (30.72)	0.90	0.89	0.89	0.90
Sub-factor: Work conditions *Ex: Works in an office; Wears a suit*		*2 questions*	2.33 (10.15)	*0.67*	*0.67*	*0.67*	*0.66*
General engineering efficacy Ex: Design a good website for my school; Use maths to help plan and build something; Explain why we recycle paper	10-pt confidence levels (0 – 100%)	22 questions	9.53 (45.24)	0.94	0.95	0.95	0.95

Sub-factor 1: Mathematics learning *Ex: Top grade in mathematics; Learn algebra/geometry*		*3 questions*	*1.87 (8.51)*	*0.87*	*0.77*	*0.89*	*0.89*
OUTCOME FACTOR **Aspiration to become an engineer**	6-pt scales (very likely – very unlikely)	2 questions	1.65 (82.64)	0.79	0.84	0.83	0.84

Table 3: General means for predictor and outcomes factors; Comparisons between Chinese regions and China/Hong Kong

Predictor factors	General mean (China)	Chinese regions				China/Hong Kong		
		Beijing	ShanXi	Guangzhou	F	China	Hong Kong	F
Practical (learning) activities	4.27	4.37	4.08	4.27	NS	4.27	3.84	353.77***
Knowledge about engineering	*3.16*	*3.30*	*2.96*	*3.12*	*11.71****	*3.16*	*2.92*	*49.09****
Engineering activities in school	0.29	0.18	0.09	0.92	2356.12***	0.29	0.25	11.51***
Encouragement by teacher	4.05	4.17	3.65	4.49	39.70***	4.05	4.04	NS
Encouragement by parent	4.32	4.41	4.16	4.32	14.94***	4.32	3.76	497.37***
Extracurricular engineering activities	2.40	2.67	2.13	2.20	32.46***	2.40	1.90	285.89***
BTE (Build/Take apart/Explain)	*3.44*	*3.61*	*3.18*	*3.38*	*20.92**	*3.44*	*2.82*	*341.39****
Motivation to engage in engineering activities	3.71	3.74	3.59	3.78	4.78**	3.71	3.29	203.86***
Social motivation	*3.64*	*3.72*	*3.54*	*3.55*	*4.06**	*3.64*	*3.45*	*29.42***
Perception of engineers	4.47	4.45	4.41	4.63	8.31***	4.47	4.04	365.16***
Presentation of engineers	*3.25*	*3.21*	*3.29*	*3.24*	*NS*	*3.25*	*3.24*	*NS*
General engineering efficacy	58.71	61.49	54.99	57.10	19.41***	58.71	52.49	126.17***
Mathematics efficacy	*63.05*	*65.95*	*57.33*	*64.30*	*21.79****	*63.05*	*55.70*	*106.82****
Outcome	3.23	3.29	3.03	3.42	9.59***	3.23	2.85	95.96***

*: p<0.05; **: p<0.01; ***: p<0.001

Table 4: Correlation matrix for between main predictor factors and outcome factor (China only)

	1	2	3	4	5	6	7	8	9
1. Practical (learning) activities related to STEM subjects	1.0	-.116**	.426**	.533**	.523**	.544**	.388**	.533**	.489**
2. Participation in engineering related activities in school		1.0	.196**	.094**	.102**	.104**	.153*	.057*	.142**
3. Encouragement to participate by teachers			1.0	.364**	.375**	.305**	.231**	.353**	.323**
4. Encouragement to participate by parents				1.0	.506**	.474**	.414**	.391**	.454**
5. Extra-curricular engineering activities					1.0	.509**	.291**	.427**	482**
6. Motivation to engage in school-based engineering activities						1.0	.530**	.495**	.665**
7. Perceptions of engineers/engineering							1.0	.386**	.402**
8. General engineering efficacy								1.0	.395**
9. Outcome: Aspiration to become an engineer									1.0

*: p<0.05; **: p<0.01

Table 5: Within China Demographic Comparisons of means for predictor and outcomes factors (general mean for each factor in Table 3)

	Personal characteristics										School Type+		
	Sex			Age				Relative as engineer					
PREDICTOR FACTORS	Male	Female	F	S2	S4	S6	F	Yes	No	F	Grammar	Vocational	F
Practical (learning) activities	4.39	4.13	49.00***	4.33	4.27	4.20	2.60	4.54	4.18	69.62***	4.34	3.94	54.94***
Knowledge about engineering	*3.27*	*3.04*	*13.26****	*3.26*	*3.13*	*3.11*	*1.70*	*3.67*	*2.98*	*84.80****	*3.22*	*2.96*	*8.06***
Engineering activities in school	0.28	0.30	0.69	0.25	0.21	1.29	280.63***	0.33	0.30	1.63	0.14	0.15	5.37*
Encouragement by teacher	4.10	4.00	2.02	4.38	3.91	4.12	19.32***	4.28	3.99	11.66***	4.10	3.41	52.01***
Encouragement by parent	4.33	4.30	0.64	4.21	4.39	4.22	9.60***	4.66	4.19	91.42***	4.36	4.13	16.09**
Extracurricular engineering activities	2.55	2.23	26.59***	2.27	2.48	2.37	3.78*	2.79	2.24	56.17***	2.49	2.55	0.33
BTE (Build/Take apart/Explain)	*3.71*	*3.13*	*106.26****	*3.32*	*3.46*	*3.54*	*3.42**	*3.77*	*3.32*	*40.82****	*3.47*	*3.35*	*2.16*
Motivation to engage in engineering activities	3.82	3.58	25.82***	3.58	3.73	3.83	5.76**	3.93	3.63	27.19***	3.73	3.51	9.34**
Social motivation	*3.65*	*3.63*	*0.04*	*3.58*	*3.66*	*3.68*	*0.74*	*3.70*	*3.62*	*1.13*	*3.63*	*3.76*	*1.90*
Perception of engineers	4.45	4.50	1.99	4.33	4.52	4.54	9.41***	4.61	4.45	11.68***	4.46	4.30	7.66**
Presentation of engineers	*3.23*	*3.26*	*0.63*	*3.10*	*3.29*	*3.36*	*9.76****	*3.16*	*3.27*	*4.62**	*3.19*	*3.49*	*24.68****

General engineering efficacy	59.33	58.10	1.67	59.73	59.12	55.08	5.09**	65.12	56.49	59.69***	61.48	48.29	95.08***
Mathematics efficacy	*63.81*	*62.21*	*1.88*	*67.34*	*62.78*	*55.54*	*19.17****	*69.36*	*60.46*	*40.89****	*67.06*	*43.44*	*217.08****
OUTCOME	3.41	3.04	31.80***	2.79	3.30	3.49	14.24***	3.59	3.10	37.96***	3.21	3.12	0.93

+: Data for this variable was not collected in Guangzhou

*: p<0.05; **: p<0.01; ***: p<0.001

Table 6a and b: Hierarchical regressions relating Predictor and Demographic variables with engineering outcome in China and Hong Kong

Coefficients

Model	China Factors					Hong Kong Factors				
		B	St. Error	Beta	t		B	St. Error	Beta	t
1	Constant	3.17	0.25		12.95***	Constant	3.40	0.13		26.83***
Demographic	Engineer in family	0.04	0.09	0.16	4.67***	Engineer in family	0.29	0.06	0.12	4.99***
	Age	0.22	0.08	0.10	2.77**	Age	0.11	0.04	0.06	2.56**
	Sex	-0.29	0.10	-0.09	-2.71**	Sex	-0.49	0.06	-0.18	-7.84***
2	Constant	-2.04	0.25		-6.07***	Constant	-0.97	0.19		-4.75***
Predictor	Engineer in family	0.58	0.07	0.02	0.88	Engineer in family	0.03	0.04	0.01	0.60
&	Age	0.15	0.06	0.07	2.43*	Age	0.14	0.03	0.08	4.45***
Demographic	Sex	0.01	0.09	0.00	0.09	Sex	-0.15	0.05	-0.06	-3.16**
	Eng Efficacy	0.00	0.00	-0.01	-0.15	Eng Efficacy	0.03	0.00	0.04	1.98*
	Perception of Eng	-0.07	0.06	0.04	1.32	Perception of Eng	0.10	0.03	0.06	2.89**
	Practical learning	0.28	0.08	0.14	3.69***	Practical learning	0.14	0.05	0.08	3.08**
	Teacher encourage	-0.07	0.03	-0.06	-1.96*	Teacher encourage	-0.08	0.03	-0.06	-2.69**
	Parent encourage	0.20	0.05	0.13	3.86***	Parent encourage	0.05	0.03	0.03	1.50
	Motivation to eng	0.62	0.05	0.44	12.27***	Motivation to eng	0.72	0.03	0.54	22.44***
	In-school eng activity	0.21	0.10	0.06	2.03*	In-school eng activity	-0.08	0.06	-0.02	1.20
	Extracurricular eng activity	0.17	0.05	0.12	3.52***	Extracurricular eng activity	0.19	0.03	0.12	5.89***

*: p<0.05; **: p<0.01; ***: p<0.001