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Aspiring to become an engineer in Hong Kong: Effects of engineering education and demographic background on secondary students' expectation to become an engineer[1]

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Abstract

Many post-industrial societies have seen a decline in secondary school students' aspirations to become an engineer. Hong Kong (HK) is a post-industrial region within a larger industrialising society where no current study identifies engineering aspirations of secondary students. A representative sample of HK (3724 students/23 schools) explored engineering attitudes, perceptions, motivation, efficacy and curricular/extracurricular experiences using a purposely defined questionnaire. Contributions of these factors to students' aspirations were differentiated into individual and school contexts using hierarchical linear modelling and structural equation modelling. Descriptive analyses identified boys and younger students in single-sex schools had the most positive attitudes towards engineering but school-based engineering opportunities did not provide significant contributions to students' aspirations. Aspirations were affected by students' engineering efficacy, practical 'hands-on' experience and limited science, technology, engineering and mathematics (STEM) curricular experience. Similarities between HK and many post-industrial societies, and curriculum/pedagogical implications concerning efficacy for secondary school engineering education are identified.

Key Words: Engineering career, Engineering learning systems, Secondary schools, Theory of planned behaviour, Engineering aspiration

Aspiring to become an engineer in Hong Kong: Identifying Demographic, Curriculum and Pedagogic Opportunities for Engineering Education among Secondary School Students

Introduction

The role of engineering has been essential for the continuing development of Hong Kong (HK). Yet, to our knowledge, there are no studies of attitudes, experiences or activities that may lead HK high school students towards the further study of/careers in engineering. HK has a history of innovative engineering and been identified as a highly advanced post-industrial society (Wei, 2005). At the same time, HK shares a common culture with its industrialising motherland - China, where there has been much interest and uptake in engineering (CPGPRC, 2010; MoE China, 2012). HK also shares post-industrial concerns of high demand but relatively low uptake for engineers (ETB, 2005; Katehi, Pearson, & Feder, 2009; King, 2008; Maillardet, Martlando, & Morling, 2007) and the need to inspire young people to select engineering (or associated science, technology, mathematics [STM] subjects) in higher education and subsequent career. These concerns are an economic and national priority for many governments and organizations worldwide (Borrego & Bernhard, 2011; NAE, 2009; OECD, 2011; RAEng, 2012).

While HK shares statehood with rapidly industrialising mainland China, the region is encountering engineering supply problems similar to many Western, post-industrial countries, such as the United States, United Kingdom, Australia (Brophy, Klein, Portsmore, & Rogers, 2008; Wei, 2005)[1]. As found in these other countries, there is a range of school-based and other engineering opportunities open to secondary school students. Yet, curricular and extracurricular

[1] The authors acknowledge that engineering/technology/science supply problems at the tertiary level may be an overgeneralisation, especially where countries like Sweden and Finland tend to have a substantially higher rate of entry into engineering/technology than other Western countries (van Langen & Dekkers, 2005), yet across Europe there has generally been an increasing demand/lowering of applicant numbers in science and technology (European Commission, 2004).

opportunities do not significantly enhance students' engineering aspirations (NCES, 2014). Numerous theories concerning engineering identity, motivation, efficacy and practices have been put forward to explain pipeline leakage regarding the choice of engineering career (Capobianco, French, & Diefes-Dux, 2012; Godwin, Potvin & Hazari, 2014; Matusovich, Streveler & Miller, 2010; Wang, 2013), though none of these studies have taken place in HK. Non-HK studies identify the need to understand effects of expectancy/value (Eccles & Wigfield, 2002), efficacy (Bandura, 1997), actual experiences and opportunities offered in schooling (Wang & Degol, 2013), social support (Godwin et al., 2014) and age development (Unfried, Faber & Wiebe, 2014) in establishing adolescents' engineering aspirations. In ascertaining HK student views, attitudes and experiences we initially describe the background for engineering and science, technology, engineering and technology (STEM) subjects in secondary schools followed by a larger body of engineering education research from the western literature.

Background

Hong Kong

One might expect that HK's internationally high rank in school science and mathematics (TIMSS [Mullis, Martin, Foy, & Arora, 2012] and PISA [OECD, 2010]) would promote high levels of interest in engineering study/careers as asserted in western studies (Aschbacher, Li & Roth, 2010; Godwin et al., 2014; Matusovich et al., 2010; Wang, 2013). STM[2] subjects in HK are central components in secondary school education. These subjects have been given a high priority by government and engineering organisations (HKCDC, 2015; Sin, 2007). Technology-related subjects account for 8% of the secondary school curriculum (Sin, 2007). Table 1

[2] Readers should note that the school subject of engineering is only taught to the highest year groups in HK secondary schools, hence secondary students will have greater access to STM courses rather than STEM courses.

identifies that: (1) substantial numbers of students in the Junior and Senior Secondary curriculum (S1 to S3/students aged 12-14 years and S4 to S6/students aged 15-17 years) have access to Computer Literacy or Information and Communication Technology (ICT); (2) Technology & Living is taught mainly in Junior Secondary schools, especially in female-only schools; (3) Design and Technology (DT) characterises Junior Secondary schools; (4) engineering-oriented subjects (e.g. Electronics & Electricity and Technology Fundamentals) are only offered in the few remaining technical schools; and (5) it can be assumed that all secondary school students will access SMT courses. While HK students have access to an early understanding of engineering in various design, technology and computer-based courses, there is little exposure to actual engineering topics within the curriculum (EDB, 2014). Even with exposure to broader STM subjects, there are few teachers or occupation guidance officers with backgrounds in engineering. And, students' exposure to engineering and STM may be seen to be constrained by their school, age and sex.

TABLE 1

Even with continuous STM exposure through secondary schools and some engineering-oriented courses, current university entrance analyses identify that engineering is in a slow but continuous decline as noted by decreasing local student applications (JUPAS, 2013; 2015). This low entry into engineering contrasts with the potential of organisational (school and extracurricular), pedagogic, personal, familial and cultural opportunities that surround secondary school-aged students in HK that have also been identified in a number of other post-industrial countries.

Engineering Education Studies in Post-industrial Countries

This section draws upon insights from North American (ex. Brophy et al., 2008), Northern European (ex. RAEng, 2012), and Asia Pacific (King, 2008; Ravishankar, Allen, Eaton, Ambikairajah & Redmond, 2012). It acknowledges that current understanding of effects of engineering education on students' further study/career choice may be limited by methodological and theoretical constraints (e.g. limited number of systematic or representative reviews of the impact of school-based engineering education opportunities [Borrego & Bernhard, 2011] with an overexposure of retrospective university-based studies [Godwin et al., 2014; Sheppard et al., 2010]). Current studies provide a broad focus on interventions that may change students' attitudes to engineering or draw upon samples of university students who persisted in the study of engineering (Sadler, Sonnert, Hazari & Tai, 2012). They tend not to account for the fact that children between ages 10 and 16 express high levels of aspirations for future careers; although children's perceptions may be biased by their sex, ethnicity, cultural and social capital as well as limited curricular, teacher and industrial support with regard to STM subjects (ASPIRES, 2013). In this vein, there have been calls for more studies of school-aged children and the effects of engineering experience on their desire for further study/career choice (Capobianco et al., 2012; Wang, 2013). Both reflective and school-based studies identify characteristics that may stimulate student interest but do not provide information regarding impediments to the study/career in engineering (e.g., Marra, Rodgers, Shen, & Bogue, 2012). Nevertheless, a number of studies (such as Davis, Yeary, & Sluss, 2012) have recognised the need to make engineering educational opportunities and careers more visible to the public at an age level before career decisions are made as well as considering the role of pedagogy, school and social support; thus moving to an 'engineering education research' orientation that is representative of particular societies (see

Borrego & Bernhard, 2011; Guzey, Tank, Wang, Roehrig, & Moore, 2014; Jesiek, Newswander, & Borrego, 2009).

Currents Issues in STEM Education

Low uptake of engineering programmes, however, does not indicate low exposure to engineering during secondary schooling in western and Asian post-industrial countries (ASPIRES, 2013; King, 2008; Lyons, 2006; Sohn & Ju, 2010). Engineering and STM opportunities in post-industrial countries account for 8-10% of curriculum time and student also have access to additional outreach/extra-curricular programmes (e.g. in the USA see Katehi et al., 2009). A number of key issues underlying interest in and pursuit of engineering have been identified in these studies. Issues include demographic (age, sex, family), cultural and school-based engineering experiences offered to individuals. Most school children choose careers around the age of 14 – before engagement in focused engineering-related subjects (Sohn & Ju, 2010; Tai, Liu, Maltese, & Fan, 2006; Wang, 2013). These studies suggest the need for further research on what causes this relatively early career choice, sometimes described with regard to adolescents' engineering identity (Capobianco et al., 2012). Participation rates in engineering education have been found to be lower for females than males (van Langen & Dekkers, 2005) but higher for ethnic minorities than majority ethnic groups (Maillardet et al., 2007), suggesting more focused, gender defined introductions to engineering and STM courses may be needed (Unfried et al., 2014). The expectation of uptake of careers in engineering is more likely to be explained by home and cultural background than school-based opportunities and educational experiences (ETB, 2005), especially if a parent or near relative has a career in engineering (Godwin et al., 2014).

Within schools, curriculum and pedagogy issues have been identified that affect study/participation in engineering and STM subjects. These studies note that secondary students have early and continuing access to science, technology and mathematics, although both Holman (2007) and Katehi et al. (2009) refer to engineering's true representation in schools as ST*e*M (Science, Technology, engineering, Mathematics) - where engineering does not have a clear subject identity. An Engineering & Technology Board (ETB, 2005) survey in the UK identified the importance of secondary school subject teachers encouraging academic/career choice although few teachers have an engineering background, training for engineering career advice or knowledge of engineering (Guzey et al., 2014). Student interest, efficacy and competence in mathematics has been acknowledged as fundamental to development as an engineer, yet engineering receives very little attention in school-based mathematics education (Godwin et al., 2014; Ker, 2012). Studies in higher education identify that engineering demands active skills of efficacy, innovation and entrepreneurship (Good & Greenwald, 2007), yet STM school teachers often rely on 'transmission' pedagogy (Lyons, 2006) that excludes efficacy and active skills engagement (Katehi et al., 2009). Few studies associate the 'plan and do' approach that characterises extra-curricular engineering activities with development of engineering aspirations (Moreland, Jones, & Barlex, 2008). Access to applied problem-solving and interpersonal skills may enhance engineering aspirations but these skills are unlikely to be found in secondary school classrooms (Brophy et al., 2008; Chiu et al., 2013; Lyons, 2006).

Cultural involvement in engineering combines demographic aspects with school-based activity. It acknowledges the support that can be provided by parents, teachers and peers along with school- and extra-curricular activities into a variety of situated communities that may include or exclude engineering and STM (Wang, 2013). In order to support the further study of/careers in engineering, community involvement must be domain specific (Wang, 2013) and encouraging of specific engineering/STM competencies. These domain-based competencies help to develop the student's engineering and STM capital – which, in turn, supports further study and career decisions (ASPIRES, 2013).

Insight into causes that facilitate students' aspirations in engineering may seem piecemeal in light of the range of demographic, cultural and school-based opportunities identified. The above studies rarely integrate and prioritise the many opportunities offered to students. Research methods have been narrowly focused on key STM problems without acknowledging the complex contexts of STEM; for example, teacher enhancement of gendered approaches to engineering education (Unfried et al., 2014). Samples of students can constrain the outcomes of studies when researching a single class, school or community. We gain only limited insight from reflective studies of university students who have already successfully navigated the engineering pipeline (e.g. Sheppard et al., 2010). Limited samples, reflective methods and broad STM concerns, as well as piecemeal experiences and competencies, are likely to constrain the domain-specific experiences and competencies (Wang, 2013) that are required for insight into students' decisions to pursue further study/careers in engineering.

Conceptualising Students' Orientation towards Study/Careers in Engineering; Theories of Identity, Efficacy and Planned Behaviour

If the literature concerning expected careers in engineering is extended to higher education, a different perspective arises. Drawing on applications of expectancy-value identity theory (Eccles & Wigfield, 2002), self-efficacy theory (Bandura, 1997), social cognitive career theory (SCCT; Mau, 2003) and the theory of planned behaviour (TPB; Ajzen, 2002), researchers such as Lucas, Cooper, Ward & Cave (2009) have related educational and work placement experience to engineering career attitudes and entrepreneurship. These diverse theories and experiences link self-efficacy with outcome aspirations and goals. They emphasise that domain-specific experiences will affect the individual's choice to approach or avoid the decision to pursue a particular career.

The importance of these theories in identifying a background for engineering and STM is explained by Wang and Degol (2013): '(The) STEM pathway is composed of a series of choices and achievements that commence in childhood and adolescence… Achievement-related behaviours… related to expectations for success and value attached to the various options perceived as available' (p.305). More specific is to the realisation that domain-specific study/career pathways are affected by 'cultural norms, behaviour, social experiences, aptitudes and affective reactions to previous experience' (p.305). Expectancy-value is one theory which combines psychology, biology and behaviour in the development of engineering and STM identities (Matusovich et al., 2010; Unfried et al., 2014; Wang & Degol, 2013), thus moving beyond the focus of a singular factor affecting aspirations. Underlying expectancy-value are beliefs in personal efficacy and persistence to meet a valued objective or goal (Eccles & Wigfield, 2002). And these valued goals will be affected by classroom experiences, curriculum exposure, educational contexts (such as single-/mixed-sex schooling) and teacher/parent/peer support. Wang & Degol (2013) particularly note that exposure and efficacy developed within secondary school mathematics and science curricula strongly relate to an individual's persistence in the engineering/STM pathway. Underlying this motivational experience is an individual's domain-specific feelings of efficacy.

Self-efficacy theory offers another understanding of the factors which lead to that sense of study/career control (Lucas et al., 2009). Self-efficacy draws upon two aspects and relates directly to experiences encountered by students: the self-perception of control (Ajzen, 2002) and the belief in one's ability 'to organize and execute the courses of actions required to produce given attainments' (Bandura, 1997 p.3). Key amongst these aspects is the authentic experience of effective control within the domain of interest. Social norms also play an important role in defining domain and the significance of the activities for the individual. Students with authentic work place experience will develop an enhanced sense of self-efficacy and control with respect to that class of activity (Lucas et al., 2009). Over time, such experiences increase the probability of an individual engaging in similar behaviours, changing self-identification, and developing an orientation to social norms aligned with that behaviour. Authentic experience has been found to positively affect students' attitudes, perceptions and motivation with regard to career aspirations (Beard, 1998). Self-efficacy, thus developed, is considered a key element in the prediction and actual practice of career choice (Mau, 2003; Pajares, Britner & Valiante, 2000); although educational experiences are rarely geared for the development of self-efficacy (Lucas et al., 2009). One potential reason for this lack of gearing regarding engineering and STM is the lack of domain-specific experience such that a competence/confidence spiral is unlikely to take place. Allied to the spiral is the need for an instrument that can measure engineering's specific efficacy that is not too general and is related to actual experiences of secondary school students.

TPB (Ajzen, 2002) articulates that aspiration decisions move beyond attitudes and allows for the influence of two other factors: prevalent social norms required to achieve a specific (career) outcome and the individual's belief in his/her capacity to exert the necessary level of control over that behaviour to achieve the outcome. TPB draws upon three independent variables: behavioural belief (the possibility that a behaviour will lead to a certain consequence [e.g. studying mathematics and a STM career]); normative belief (social norms or pressures to perform/not perform a behaviour); and perceived behavioural control (whether an individual feels that he/she can efficaciously perform a particular behaviour). The combination of these variables moves beyond identity and cognitive theories about behaviour and can explain intention to aspire to a particular behaviour that will ultimately dictate an individual's career choices over time. The theory has been applied within a one-time data collection (as in a survey) where the independent variables can be used to explain expected behaviour and intention (Harding, Mayhew, Finelli, & Carpenter, 2007; To, Lai, Lung, & Lai, 2014).

Studies undertaken in post-industrial countries concerning experiences and theoretical conceptualisations likely to affect students' choice of further study/careers in engineering have identified a wide range of factors that should be accounted for in designing a HK-based study. Minimally, the study should focus on the adolescent age group and sex that characterises secondary schooling. Identity and SCCT theories includes experiences that directly arise from school curriculum and extra-curricular activities as well as social context factors, attitudes and norms supported by teachers, parents and peers – especially if a close relative is an engineer. Underlying all of these aspects will be domain-specific experiences and efficacy/control in the perception/undertaking of engineering tasks.

The Current Study

This study extends the current literature and understanding of engineering career expectations by: a) providing a representative sample of HK secondary school students' attitudes and experiences with regard to study/career choice in engineering that will overcome the current piecemeal understanding of engineering aspirations; and b) extending beyond previous attitude-oriented studies to consider the role of engineering efficacy in students' orientation to engineering. Research questions include:

1. Descriptively, what are the current attitudes, perceptions, motivations, experiences and efficacy regarding engineering held by secondary school students in HK and how can we characterise differences between student aspirations?
2. How do attitudinal, perceptual, experiential factors contribute to students' engineering aspirations?

Methods

Sample

The sample was devised to be a proportional, stratified and clustered representation of HK secondary schools and their students (Table 2). The 23 participating schools were represented proportionally by education district, school-type and funding source. 3,724 students participated, fulfilling stratification criteria by age and sex, and collection of student data was clustered by randomly selected whole classes (limiting within-school disruption). Ethical approval was agreed at school and participant levels. A sample size calculation showed very good representation, with a confidence level of 98% and confidence interval of 2 (Raosoft, 2014).

TABLE 2

Measures

Factors likely to affect students' engineering aspirations include demographic/background, as well as engineering perceptions, motivation, curricular/extra-curricular experiences and efficacy. This range of questions has not been integrated into a singular questionnaire for use in HK secondary schools previously. The questionnaire developed for this study was modelled on an engineering entrepreneurship survey among university students in the USA; the Education and High Growth Innovation project [EHGI] (Good & Greenwald, 2007). EHGI drew on the articulation of self-efficacy theory (Lucas et al. 2009) and recorded demographic aspects of students, attitudes, perceptions and efficacy including types of experience (curricular and extra-curricular) and skills characteristic of engineering. These question groupings (with the exception of efficacy) also characterised a more general STM-based questionnaire for secondary school students in the USA (Aschbacher et al., 2010).

Question groupings (Table 3) were assessed by tick boxes, frequencies and Likert scales. The questionnaire was validated (ecological, face and content) in pre-pilot and pilot testing in HK non-sample schools. Validation included both English and Cantonese versions of the questionnaire; the Cantonese version was back-translated to ensure comparability of terms and relevance to local engineering experience. The survey was undertaken as a one-time opportunity – access to schools and students could only take place in one sitting, a methodological approach similar to Harding et al. (2007) and To et al. (2014).

Questionnaire Factor Analysis

An Exploratory Factor Analysis (EFA) with principal factor extraction was conducted on a HK pilot sample, examining underlying factor structure and ascertaining whether item groups versus a singular factor characterised the questionnaire (Worthington & Whittaker, 2006). The EFA, using Varimax rotation, was undertaken on 909 questionnaires. Analysis produced a Kaiser-Meyer-Olkin (KMO) of 0.910 – showing sampling adequacy for analysis and Bartlett's Test for Sphericity (X^2[5050] = 31562.16, $p<0.001$) – showing that data were appropriate for factor analysis (Tabachnik & Fidell, 1996). Criteria for the retention of factors included minimum eigenvalue of 1.0, pattern coefficients greater than 0.45 and interpretability (Pett, Lackey & Sullivan, 2003). Factors related well to the nine, logic-based questionnaire item-groups (Table 3). Each factor was assessed for reliability using the 'alpha-if-item-deleted' test to ensure that only key contributing questions were included in each factor item-group. Each factor reached satisfactory levels of reliability (McMillan & Schumacher, 2001), with the exception of parental encouragement; average reliability was 0.83. Use and reliability of these factors were further assessed on the non-pilot sample (2,815 questionnaires), confirming the same factor structure as the pilot sample; average reliability for the non-pilot was 0.83. As the same factor structure was evident for the pilot and non-pilot samples, both were combined to provide a full HK sample; average reliability (3,724 questionnaires) was 0.85.

Item-groups were then divided into Outcome and Predictor factors. Outcome was measured by single variable: Engineering aspiration was comprised of two questions ‘desire to know more about engineering’ and ‘desire to become an engineer’. Predictor factors were based upon students’ engineering-oriented attitudes, motivations, activities, perceptions and engineering efficacy. As displayed in Table 4, there were significant and consistent Pearson product-moment correlations between many of the Predictor factors, although only a few of these correlations were greater than 0.5.

TABLES 3 and 4

Statistical Model and Analysis Plan

Initial descriptive statistics explored for factor differences related to main demographic, cultural/social background and school attended. Once descriptive differences were identified, further analyses were undertaken which acknowledged that student responses may be nested in in distinct levels of school and individual experience. To this end, a hierarchical linear model analysis [HLM] (HLM 7, Scientific Software International, Inc.) was undertaken for the outcome factor (Engineering aspiration), testing for heterogeneity at individual and school levels (Raudenbush & Bryk, 2002). Scores within each factor were standardised to overcome problems associated with diverse score ranges among factors. The variance explained by the test was found to be heterogeneous (X^2[22] = 45.54. p<0.003), suggesting that aspirations may be nested at both individual and school levels (Woltman, Feldstein, MacKay & Rocchi, 2012). However, HLM analysis also showed that none of the school-level factors were found to contribute significantly to outcome variance. This indicated that variance found was likely to be evenly spread across these representative HK schools and commonalities of the curriculum weighed against the different types of school.

The HLM analysis results drove us to conduct structural equation modelling (SEM; Byrne, 2010) that focused on how the predictor (as opposed to contextual) factors may be used in an application of TPB to explain Engineering aspiration. To use the model, questionnaire factors were fit into Ajzen's (2002) TPB constructs of behavioural belief, normative belief, perceived behavioural control and intention (see Figure 1)[3]; as questionnaire completion was a one-time opportunity, only intention was used as indicative of engineering aspiration. Standardised scores for all predictor factors were included in the model except Motivation to engage – which was withdrawn due to its high correlation with other predictors (averaging over 0.43) associated with problems of multicollinearity. Data were analysed using SEM procedures with SPSS AMOS 21.0 (Arbuckle, 2012); using the maximum likelihood method of estimation and bias-corrected bootstrap method to establish confidence intervals for the potential mediation or suppression effects (Cheung & Lau, 2008) [with 1,000 bootstrap samples at 95% confidence intervals so that Type I error rate can be lowered (Byrne, 2010)].

Results

Differences by Individual, Social, and Cultural Background

[3] Approximation was undertaken with a group of 5 researchers covering areas of engineering, psychology and education who reviewed questionnaire factors and items in relation to Ajzen's categories. Only upon total agreement among researchers were factors/items assigned to Ajzen's categories.

Means of student attitudes, experiences, motivation, efficacy and engineering career outcome for the main predictors showed that students had limited and variable engineering education experiences (Table 3): There were moderately positive means for Practical (learning) activities, Encouragement by teacher, Encouragement by parent, Motivation to engage in engineering activities, Perceptions of engineers and Engineering efficacy. Within-school and Extracurricular engineering activities were poorly rated and showed limited experience of these activities. These descriptive statistics were then used to identify how student demographic characteristics differed in relation to predictor and outcome factors. After ascertaining normal distribution and homogeneity of variance among predictor and outcome factors, ANOVAs and linear regressions showed (Table 5):

Demographic Analyses

Sex differences**:** Boys, generally, were more involved in engineering activities (Practical (learning) activities, Extracurricular engineering activities, Motivation to engage in engineering activities, Engineering efficacy and Engineering aspiration). Boys also received higher levels of Encouragement by teachers and parents. There was no sex difference in Perception of engineers. Girls, on the other hand, showed slightly more involvement in Engineering activities in school.

Age differences**:** Younger students were generally more involved in engineering activities (Practical (learning) activities and Engineering efficacy) and received higher levels of Encouragement by teachers and parents. There was no significant age difference in Perception of engineers. Students in the mid-years were slightly less involved in within-school Engineering activities, were more highly Motivated to engage in engineering and had the highest mean in the Engineering aspiration. The oldest students did not show high levels for any of the attitudinal, motivational or perceptual factors.

***Family engineering background and ethnicity*:** Students with a relative who was an engineer showed high levels in all aspects of engineering involvement and Engineering aspiration. Differences between HK-born and non-HK students showed higher levels of Engineering aspiration among students from industrialising countries than students from post-industrial countries; non-HK students were also more involved in Extracurricular engineering activities.

***School type*:** Male-only schools showed more involvement in engineering activities, including: Practical (learning) activities, Encouragement by teachers and parents, Extracurricular engineering activities, Motivation to engage in engineering activities, Engineering efficacy and Engineering aspiration. Female-only schools showed higher Perception of engineers and, interestingly, Engineering activities in school.

Predictor and outcome factors

Linear regressions identified that each predictor factor was significantly related to the outcome factor (Table 6). When proportion of variance within each of the regressions was considered, Motivation to engage in engineering activities stood out as the strongest indicator of future involvement in engineering; but this insight may be confounded by the factor's high correlation to all other predictor factors (see above). Variance in other predictor factors that may affect outcome included Practical (learning) activities, Extracurricular engineering activities and Engineering efficacy. And, very limited contribution to the Engineering aspiration could be attributed to formal school activities.

Another way of exploring this descriptive data is to identify differences between those students who have scored high (5.0 to 6.0) on the Outcome factor and ascertain whether these students are distinct from mid- and low-scoring students. The high-scoring students accounted for nearly 11% (nearly 400 students) of the full sample. As might be expected, these students were most likely to be male, attend a male-only government funded private Direct Subsidy Scheme (DSS) schools and were in the S2 or S4. There was no indication that birthplace mattered. High-scoring students had significantly more close relatives engaged in engineering than other students; they also had significantly higher means for all of the Predictor factors with the exception of Engineering activities within-school (Table 7). High-scoring students were particularly strong in their Engineering efficacy. Despite descriptive analyses showing differences between demographic and predictor factors on outcome, these results offer limited insight as to factors likely to contribute to Engineering aspiration.

TABLES 5, 6 and 7

SEM Analyses: Developing Explanations for Engineering Aspiration**:** A structural equation model (Figure 1) was set up based on the definitions from Ajzen (2002) and To et al. (2014) as an approximation of TPB: *Behavioural belief* identifies that engineering study will enhance aspiration via curricular and extra-curricular experience; *Normative belief* or pressures may enhance aspirations via family members who are engineers, encouragement by teachers or parents and positive perceptions of engineers; *Perceived behavioural control* identifies that engineering problems can be competently overcome via engineering efficacy and practical learning activities; and *Intention* in this one-time survey is identified by the outcome factor – Engineering aspiration. Figure 1 attests to the goodness of fit of the approximated TPB model. CMIN/df is somewhat higher than normal expectations but the finding can be explained by the effect of a large sample size that boosts chi square test observations (Schumacker & Lomax, 2004). Model fit indices like comparative fit index (CFI) = .95 and Root Mean Square Error of Approximation (RMSEA) = .05 indicating the model fits the data very well. Overall, the model accounted for 40% of the variance in explaining Engineer aspiration: there was a moderate relationship between behavioural beliefs that associate school and extra-curriculum factors with intention (β = .22); normative beliefs did not significantly affect intention; and perceived behavioural control had a very strong relationship to intention (β = .62). Thus, actual experience of engineering activities with the associated feeling of efficacy was most likely to affect students' Engineering aspirations. Limited contributions were derived from curriculum and after-school experience of engineering. Attitudes and family/teacher support were unlikely to stimulate or maintain students' Engineering aspirations in this sample.

FIGURE 1

Discussion

Similar to a number of post-industrial countries, with an increasing demand for engineers HK faces a reduction in the number of students aspiring to become an engineer. All HK secondary school students have exposure to STM courses, and students generally possess positive attitudes towards activities associated with engineering, motives to engage in engineering activities, perceptions of engineers and engineering efficacy. At the same time, they showed limited involvement in school-based and extracurricular engineering activities and a low engineering aspiration. Male students had significantly higher ratings than females for most of the engineering predictor and outcome factors although males and females rated perceptions of engineers equally. The differences accountable by age consistently showed that younger students (12-13 years old) gave higher ratings in most predictor factors while the oldest students had lower/lowest ratings in these factors. Mid-aged students had high ratings for a desired career in engineering.

These sex and age findings align with studies conducted in other post-industrial countries (Sohn & Ju, 2010; RAEng, 2013; Tai et al., 2006) where males and younger students showed more positive orientations towards engineering than females and older students. Especially with regard to age and provision of curricular and extracurricular engineering experiences, findings parallel western studies where younger children expressed higher levels of STEM interest but it is the older students who were provided more STEM opportunities (ASPIRES, 2013; Borrego & Bernhard, 2011; Guzey et al., 2014). Positive factor responses by students with relatives who were engineers align with existing studies (e.g. Tai et al., 2006) and add critical insight into the role that family/cultural capital may add to the expectation of becoming an engineer (ASPIRES, 2013; ETB, 2005). Ethnic minorities' responses were similar to other HK students, a point of difference from existing western studies (e.g. Maillardet et al., 2007).

School-based differences provide limited insight; although descriptive analyses showed similarities to post-industrial studies while variance characterised by these factors proved non-significant in the HLM. At the same time, we note that the higher engineering aspirations of students attending male-only schools which may align with male stereotypical imaging of engineering (Maillardet et al., 2007).

The relationship between predictor and outcome factors provides insight into the pedagogic and social pedagogic contexts within which the aspiration to become an engineer may be promoted. Practical learning activities, Engineering efficacy and, to some extent, Motivation to engage were the most telling of the predictor factors in relationship to Engineering aspirations. Each of the predictors had a (moderately) positive mean and each provides opportunities to undertake making, taking apart, experimenting and explaining activities related to engineering – such that the student can do these competently and efficaciously. These activities are not normally included in class work. Underlying these factors is an active, curiosity-driven, outlook that has been recognised to a limited extent in the literature (e.g. ETB, 2005). Like Katehi et al.

(2009), the survey reveals that this opportunity to engage was rarely taken-up within school-based or extra-curricular engineering activities. Only a quarter of the students attended school-organised engineering activities such as visits from local universities, participating in engineering clubs and visiting local engineering firms. Noticeably, while all students had access to technology and pre-engineering courses in their secondary schools, they were unlikely to make positive outcome attributions regarding this experience. This poor relationship between engineering experience and outcome was not affected by high levels of teacher and parent encouragement to engage in STM activities. Based upon the existing literature, we may speculate that teachers may require greater latitude to exercise their engineering knowledge within both formal and informal curricula (ETB, 2005; Guzey et al., 2014; Holman, 2007; Katehi et al., 2009). HK classrooms may be unlikely to offer this pedagogic opportunity as HK teachers have been characterised as operating under Confucian Heritage practices wherein teachers maintain strict control over presentation of theory-based curriculum and pupils are described as passive (Biggs, 1996). Focusing solely on the descriptive results we may perceive an initial view of Engineering aspiration as dominated by individual students' Engineering/Science Capital. According to Zimmerman and Bell (2012), when students engage in a learning activity, their affective and epistemic resources are influenced by their social interactions (with family members, teachers, and peers), cultural influences (such as school type, perceptions of the engineering profession) and curricular and pedagogic approaches within schools. A mix of all of these factors appear fundamental to STEM-based capital (ASPIRES, 2013). Expanding data collected to include Engineering efficacy, a factor unlikely to be encouraged in these HK classrooms – but having the strongest of relationships to Engineering aspiration – provides an opportunity to reappraise the above results.

Our HLM and SEM analyses moved away from more traditional engineering identity and SCCT models. HLM results downplayed the effect of the school and contextual factors on Engineering aspiration, and allowed for an application of TPB. Due to the common curriculum and extra-curricular opportunities found across all secondary schools in HK, these school-based/cultural experiences offered little in the way of variation of engineering aspiration for students. Engineering efficacy and Practical learning experience were, thus, unlikely to be encouraged in these HK classrooms – while SEM analysis showed that these factors had the strongest relationship to Engineering aspirations in our sample. For students to have high efficacy scores, they will have had strong perceptions of control (from Ajzen, 2002) and ability 'to organize and execute' (from Bandura, 1997) actions capable of producing engineering attainments. These factors involved students' engagement and reflection upon engineering-oriented actions that require more commitment than simple 'plan and do' (Moreland et al., 2008) – with the belief that the student can succeed in designing, building, working with others, and excel in applied mathematical understanding (Brophy et al., 2008; Ker, 2012). With a focus on the engineering domain, the SEM figure supports Wang & Degol's (2013) assertion that an engineering pathway 'is composed of a series of choices and achievements… related to expectations for success', increasing the value of perceived options in engineering. Given this interpretation of results, a few particular follow-up points arise that may apply to HK schools as well as schools in other post-industrial societies: 1) even though HK has realised the need to promote STEM education (HKCDC, 2015) it is foregoing the development of engineering because its STEM promotion is only planned to take place through traditional curriculum areas of science, technology and mathematics (STM); 2) while we have a number of ideas of what successful engineering efficacy is meant to achieve, there are few studies that have actually pedagogically explored which school (and other) experiences are likely to promote students' engineering efficacy; 3) if engineering efficacy is introduced within a STEM programme it may be helpful to introduce actual/domain specific engineering courses (instead of aspects of engineering within STM) and these courses should take place from the earliest years in secondary school. (These engineering courses may be taught by existing teachers who have engineering degrees.)

Even though this representative survey showed HK students have a positive view of engineering and engineers and they studied many STM background courses these experiences were unlikely to make a significant contribution to students' engineering aspirations. Students' engineering career orientations were likely to take place in a rather stereotypical manner – more likely to affect boys than girls, excluding engineering courses for younger students that express highest levels of engineering interest, and allowing career insight and support to take place via family-based cultural capital. While the HK education system realised the importance of engineering and STEM, it will need to move away from traditional STM approaches if the leakage in the engineering/STEM pipeline is to be minimised.

References

Ajzen, I. (2002). Perceived behavioral control, self-efficacy, locus of control and the theory of planned behavior. *Journal of Applied Social Psychology, 32*(4), 665-683.

Arbuckle, J.L. (2012). *AMOS 21.0 user's guide*. Chicago: SPSS Corporation.

Aschbacher, P.R., Li, E., and Roth, E.J. (2010). Is science me? High school students' identities, participation and aspirations in science engineering and medicine. *Journal of Research in Science Teaching, 47*(5), 564-582.

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

Bandura, A. (1997). Personal efficacy in psychobiologic functioning. In G.V. Caprara (Ed.), *Bandura: A leader in psychology* (pp. 43-66). Milan, Italy: Franco Angeli.

Beard, D.F. (1998). The status of internships/cooperative education experiences in accounting education. *Journal of Accounting Education, 16*(3), 507-516.

Biggs, J. (1996). Western misconceptions of the Confucian-heritage learning culture. In D. Watkins and J. Biggs (Eds.), *The Chinese learner: Cultural, psychological and contextual influences* (pp. 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.

Byrne, B.M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming* (2nd ed.). New York, NY: Routledge/Taylor & Francis Group, New York, NY.

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.

Central People's Government of the People's Republic of China (CPGPRC). (2010). *National Outline for Medium- and Long-Term Talent Development (2010-2020) (in Chinese)*. Retrieved from http://www.gov.cn/jrzg/2010-07/29/content_1667143.htm

Cheung, G.W., and Lau, R.S. (2008). Testing mediation and suppression effects of latent variables: Bootstrapping with structural equation models. *Organizational Research Methods, 11*(2), 296-325.

Chiu, J.L., Macolm, P.T., Hecht, D., DeJaegher, C.J., Pan, E.A., Bradley, M., and Burghardt, M.D. (2013). WISEngineering: Supporting precollege engineering design and mathematical understanding. *Computers & Education*, *67*, 142-155.

Davis, C.E., Yeary, M.B., and Sluss, J.J. (2012). Reversing the trend of engineering enrollment declines with innovative outreach, recruiting, and retention programs. *Education, IEEE Transactions*, *55*(2), 157-163.

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

Education Bureau, Hong Kong SAR Government (EDB). (2014). *Secondary Education*. Retrieved from http://www.edb.gov.hk/en/about-edb/publications-stat/figures/sec.html

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

European Commission (2004). Europe needs more scientists: Report by the High Level Group on Increasing Resources for Science and Technology. Brussels: European Commission.

Godwin, A., Potvin, G., and Hazari, Z. (2014). *Do engineers beget engineers?* Paper presented at meeting of American Society for Engineering Education, 15-18 June, Indianapolis, IN.

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.

Harding, T.S., Mayhew, M.J., Finelli, C.J., and Carpenter, D.D. (2007). The theory of planned behaviour as a model of academic dishonesty in engineering and humanities undergraduates. *Ethics and Behavior*, *17*(3), 255-279.

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

Hong Kong Curriculum Development Council (HKCDC). (2015). *Promotion of STEM Education: Unleashing Potential in Innovation*. Hong Kong: Curriculum Development Council.

Jesiek, B.K., Newswander, L.K., and Borrego, M. (2009). Engineering education research: Discipline, community, or field?. *Journal of Engineering Education*, *98*(1), 39-52.

Joint University Programmes Admissions System (JUPAS). (2013). *JUPAS Admissions Scores of Participating-institutions 2013*. Retrieved from 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.

Ker, H.W. (2012). Engineering education and attitudes toward mathematics: A comparative study. *International Journal of Quality Assurance in Engineering and Technology Education (IJQAETE)*, *2*(1), 63-76.

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

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.

Maillardet, F.J., Martlando, F., and Morling, R.C.S. (2007). *Attracting more entrants into engineering: the UK perspective.* Paper presented at Meeting the Growing Demand for Engineers and Their Educators 2010-2020, 9-11 November, International Summit, IEEE, Munich, Germany.

Marra, R.M., Rodgers, K.A., Shen, D., and Bogue, B. (2012). Leaving engineering: A multi-year single institution study. *Journal of Engineering Education*, *101*(1), 6-27.

Matusovich, H.M., Streveler, R.A., and Miller, R.L. (2010) Why do students choose engineering? *Journal of Engineering Education*, *99*(4), 189-303.

Mau, W-C. (2003). Factors that influence persistence in science and engineering career aspirations. *The Career Development Quarterly*, *51*(3), 234-243.

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

Moreland, J., Jones, A., and Barlex, D. (2008). *Design and Technology Inside the Black Box*. London: GL Assessment.

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.

National Academy of Engineering, USA (NAE). (2009). *Engineering in K-12 Education*. Washington, DC: National Academies Press.

National Center for Education Statistics, USA (NCES). (2014). Degrees Awarded by Degree Level and Field (Data between 1966-2013, latest update in April, 2014). Retrieved from https://ncsesdata.nsf.gov/webcaspar/OlapBuilder

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.

Organization for Economic Co-operation and Development (OECD). (2011). *A Tuning-AHELO Conceptual Framework of Expected/Desired Learning Outcomes in Engineering*. OECD Education Working Papers, 60. OECD Publishing. http://dx.doi.org/10.1787/5kghtchn8mbn-en. Accessed 21 Jan 2017.

Pajares, F., Britner, S., and Valiante, G. (2000). Relationship between achievement goals and self-beliefs of middle school students in writing and science. *Contemporary Educational Psychology, 25*, 406-422.

Pett, M.A., Lackey, N.R., and Sullivan, J.J. (2003). *Making Sense of Factor Analysis*. Thousand Oaks, CA: Sage.

Raosoft. (2014). *Sample Size Calculator.* Retrieved from www.raosoft.com/samplesize.html.

Raudenbush, S.W., and Bryk, A.S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Newbury Park, CA: Sage.

Ravishankar, J., Allen, P., Eaton, R., Ambikairajah, E., and Redmond, S.J. (2012). *Taste of electrical engineering workshops for high school students*. Paper presented at Teaching, Assessment and Learning for Engineering (TALE), 20-23 August, 2012 IEEE International Conference on (T2D-14). Hong Kong.

Royal Academy of Engineering (RAEng). (2012). *Educating Engineers to Drive the Innovation Economy*. London: The Royal Academy of Engineering, UK.

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

Sadler, P.M., Sonnert, G., Hazari, Z., and Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education, 96*(3), 411-427.

Schumacker, R.E., and Lomax, R.G. (2004). *A beginner's guide to structural equation modeling*. Mahwah, NJ: Lawrence Erlbaum Associates.

Sheppard, S., Gilmartine, S., Chen, H.L., Donaldson, K., Lichtenstein, G., Eris, O., Lande, M., and Toye, G. (2010). *Exploring engineering student experience*. Center for Advancement of Engineering Education. Seattle, WA: University of Washington.

Sin, T.W. (2007). *Technology Education: A Smart Choice for both Career and Further Studies (in Chinese)*. Retrieved from 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.

Tabachnik, B.G., and Fidell, L.S. (1996). Using multivariate statistics (3rd edition). New York, NY: HarperCollins.

Tai, R.H., Liu, Q.C., Maltese, A.V., and Fan, X. (2006). Planning early for careers in science. *Science, 312*, 1143-1145.

To, W.M., Lai, L.S.L., Lung, J.W.Y., and Lai, T.M. (2014). Intent to pursue further studies among Chinese Students. *Educational Studies, 40*(3), 292-309.

Unfried, A., Faber, M., and Wiebe, E. (2014). *Gender and student attitudes toward science, technology, engineering and mathematics*. Paper presented American Educational Research Association conference, 3-7 April, Philadelphia, PA.
Van Langen, A., and Dekkers, H. (2005). Cross-national differences in participating in tertiary science, technology, engineering and mathematics education. *Comparative Education. 41*(3), 329-350.
Wang, X. (2013). Why students choose STEM majors. *American Educational Research Journal, 50*(5), 1081-1121.
Wang, M-T. and Degol, J. (2013). *Motivational pathways to STEM career choices*. *Developmental Review, 33*, 304-340.
Wei, J. (2005). Engineering education for a post-industrial world. *Technology in Society, 27*, 123-132.
Woltman, H., Feldstein, A., MacKay, J.C., and Rocchi, M. (2012). An introduction to hierarchical linear modelling. *Tutorials in Quantitative Psychology, 8* (1), 52-59.
Worthington, R.L., and Whittaker, T.A. (2006). Scale development research: a content analysis and recommendations for best practices. *The Counselling Psychologist, 34*(6), 806-838.
Zimmerman, H.T., and Bell, P. (2012). Everyday expertise: Learning within and across formal and informal settings. In D.H. Jonassen and S. Land (Eds.). *Theoretical Foundations of Learning Environments* (2nd ed.) (pp. 224–241). New York, NY: Routledge.

Table 1: Provision of engineering-related subjects in all HK secondary schools (N = 457 schools; *n* = number of schools that provide a particular subject)

School type:	**Male only (n=32)**		**Female only (n=41)**		**Co-ed (n=384)**		**Total (n=457)**	
	n	%	*n*	%	*n*	%	*n*	%
Junior Secondary (S1-S3)								
Computer Literacy	31	96.88	36	87.80	336	87.50	403	88.18
Design & Technology	10	31.25	1	2.44	213	55.47	224	49.02
Electronics & Electricity	2	6.25	0	0.00	5	1.30	7	1.53
Home Economics / Technology & Living	2	6.25	39	95.12	232	60.42	273	59.74
Technology Fundamentals	0	0.00	0	0.00	7	1.82	7	1.53
Senior Secondary (S4-S6)								
Design & Applied Technology	3	9.38	1	2.44	47	12.24	51	11.16
Information & Communication Technology	31	96.88	38	92.68	362	94.27	431	94.31
Technology & Living	0	0.00	10	24.39	17	4.43	27	5.91
Applied Learning*	12	37.50	13	31.71	139	36.20	164	35.89

Note: * Applied learning courses are offered to S5 and S6 students as elective subjects, which offer studies with strong elements linked to the vocational fields including Engineering and Production

Table 2: Characteristics of full sample based on individual, social, cultural and school aspects

Characteristics	*N* (questionnaires completed)	%
INDIVIDUAL		
Sex:		
Male	1648	44.3
Female	2032	54.6
Unreported	44	1.2
Age		
12-13	1495	40.1
14-15	1392	37.4
16-18	822	22.1
SOCIAL		
Relative as engineer		
Father	284*	7.6
Mother	27	0.7
Other close relative	757	20.3
CULTURAL		
Ethnicity		
Chinese - local born	2932	78.7
Chinese – Mainland immigrant	627	16.8
Chinese - Overseas	102	2.7
SE Asia immigrant	6	0.2
Other immigrant	57	1.6
SCHOOL		
Type:		
Coeducational (16 schools)	1251	57.8
Male-only (4 schools)	587	15.8
Female-only (3 schools)	986	26.5
Funding agency:		
Government (2 schools)	249	6.7
Aided (18 schools)	3158	84.8
DSS (3 schools)	317	8.5

Region:		
Hong Kong Island (5 schools)	878	23.6
Kowloon (9 schools)	1277	34.3
New Territories East (3 schools)	467	12.5
New Territories West (6 schools)	1102	29.6

* Of the students who were able to identify whether their father was an engineer and whether their father went to university, 154 (or 54.0% of the father as engineer sample) identified their father as a university-trained engineer.

Table 3: Item–groups for engineering questionnaire with predictor factor descriptions and measures of reliability for pilot, non-pilot and full samples (mean for full sample factors in brackets

Predictor factors with question examples	How measured	EFA			Reliability of further samples	
		Post 'alpha-if-item-deleted' questions included	Eigenvalue (Proportion of variance)	Cronbach α	Sample w/o pilot Cronbach α	Full sample with pilot Cronbach α (mean)
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)	13 questions	4.69 (36.07)	0.85	0.88	0.88 (3.84)
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)	0.70	0.70	0.91 (0.25)
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	3.33 (58.24)	0.85	0.79	0.79 (4.05)
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	0.65	0.68 (3.76)
Extracurricular engineering activities Ex: Attend engineering club at school Fixed something that was broken at home	6-pt scales (participate very frequently – no participation)	20 questions	10.62 (53.10)	0.95	0.94	0.94 (1.89)

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	3.73 (53.29)	0.84	0.86	0.86 (3.41)
Perceptions of engineers/engineering Ex: Creative Is an original thinker Can help solve environmental problems	6-pt scales (very likely – very unlikely)	19 questions	6.78 (29.46)	0.87	0.90	0.90 (3.93)
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 (43.32)	0.94	0.94	0.94 (52.53)
OUTCOME FACTOR						
Expectation to become an engineer	6-pt scales (very likely – very unlikely)	2 questions	1.71 (85.47)	0.83	0.85	0.85 (2.85)

Table 4: Correlation matrix for between main predictor and outcome factors

Predictor and Outcome factors	1	2	3	4	5	6	7	8	9
1. Active learning	1.0	.116**	.529**	.508**	.460**	.643**	.385**	.566**	.530**
2. School engineering activities		1.0	.084**	.102**	.230**	.109**	.050**	.058**	.067**
3. Teacher encourage			1.0	.427**	.223**	.394**	.301**	.370**	.260**
4. Parental encourage				1.0	.342**	.451**	.370**	.366**	.359**
5. Extra-curricular engineering activities					1.0	.432**	.216**	.350**	.423**
6. Motivation to engage in engineering activities						1.0	.474**	.508**	.707**
7. Perceptions of engineers							1.0	.389**	.378**
8. Engineering efficacy								1.0	.420**
9. Outcome									1.0

**: p<0.001

Table 5: Differences in predictor factors (and sub-factors) by demographic factors

Predictor Factors	Individual							Social/Cultural									
	Sex			Age				Engineer in family			Ethnicity			School type			
	Male	Female	F	S2	S4	S6	F	Yes	No	F	HK	Non-HK	F	Co-ed	Boys	Girls	F
Practical (learning) activities	4.08	3.65	16.16***	3.98	3.79	3.69	36.53***	4.05	3.77	80.46***	3.84	3.90	.328	3.83	4.11	3.70	48.40***
	(.80)	(.74)	(1,3457)	(.78)	(.79)	(.79)	(2,3483)	(.78)	(.79)	(1,3493)	(.79)	(1.04)	(1,3493)	(.79)	(.82)	(.74)	(2,3493)
Engineering activities in school	0.24	0.27	5.26*	0.25	0.20	0.35	44.22***	0.33	0.23	60.91***	0.25	0.24	0.68	0.26	0.16	0.29	24.66***
	(.34)	(.39)	(1,3640)	(.37)	(.34)	(.39)	(2,3662)	(.39)	(.35)	(1,3641)	(.37)	(.36)	(1,3661)	(.38)	(.23)	(.40)	(2,3673)
Encouragement by teacher	4.18	3.93	5.99***	4.21	3.95	3.78	32.81***	4.18	3.99	15.01***	4.05	3.79	2.37	4.05	4.20	3.94	6.27**
	(1.04)	(.97)	(1,2343)	(1.01)	(.98)	(.98)	(2,2360)	(0.99)	(1.01)	(1.2365)	(1.00)	(1.30)	(1,2365)	(1.00)	(1.09)	(.97)	(2,2364)
Encouragement by parent	3.84	3.70	4.82***	3.88	3.77	3.56	35.25***	4.04	3.67	124.37***	3.76	3.96	2.63	3.74	3.95	3.72	15.34***
	(.92)	(.85)	(1,3625)	(.90)	(.89)	(.82)	(2,3653)	(.87)	(.87)	(1,3664)	(.88)	(1.09)	(1,3664)	(.89)	(.94)	(.89)	(2,3663)
Extracurricular engineering activities	2.12	1.74	14.10***	1.91	1.88	1.94	1.50	2.15	1.82	117.10***	1.89	2.13	4.29*	1.92	2.15	1.73	48.61***
	(.90)	(.67)	(1,3425)	(.81)	(.78)	(.82)	(2,3449)	(.87)	(.76)	(1,3458)	(.79)	(1.01)	(1,3458)	(.80)	(.94)	(.66)	(2,3457)
Motivation to engage in eng. activities	3.55	3.23	82.79***	3.40	3.44	3.19	15.18***	3.31	3.56	40.02***	3.37	3.63	3.25	3.35	3.54	3.31	9.29***
	(1.07)	(.99)	(1,3519)	(1.04)	(1.04)	(1.01)	(2,3544)	(1.03)	(1.03)	(1,3553)	(1.03)	(1.25)	(1,3553)	(1.05)	(1.11)	(.95)	(2,3552)
Perception of engineers	3.94	3.93	0.66	3.94	3.93	3.93	0.40	4.02	3.90	14.26***	3.93	4.12	3.08	3.89	3.98	3.99	6.77**
	(.86)	(.70)	(1,3409)	(.84)	(.75)	(.67)	(2,3435)	(.75)	(.78)	(1,3445)	(.77)	(1.02)	(1,3445)	(.80)	(.88)	(.63)	(2,3444)
Engineering efficacy	54.65	50.95	5.69***	53.54	51.61	52.13	3.64**	55.72	51.41	33.98***	52.53	50.24	.77	51.23	56.62	52.92	17.00***
	(19.73)	(17.52)	(1,3305)	(19.68)	(18.07)	(17.60)	(2,3330)	(18.54)	(18.56)	(1,3339)	(18.62)	(19.97)	(1,3339)	(19.42)	(19.24)	(18.65)	(2,3338)
OUTCOME	3.10	2.65	98.41***	2.76	2.97	2.81	9.18***	3.08	2.77	35.17***	2.85	3.27	5.03*	2.82	3.10	2.78	10.89***
	(1.43)	(1.29)	(1,3608)	(1.33)	(1.38)	(1.42)	(1,3635)	(1.42)	(1.35)	(1,3645)	(1.37)	(1.69)	(1,3645)	(1.36)	(1.48)	(1.32)	(1,3644)

*p < .05, **p < .01, *** p < .001

Table 6: Predictor factors (and sub-factors) in relation to engineering outcome

Predictor Factors	Engineering outcome			
	B	ß	t	Proportion of variance explained
Constant	-0.65		-6.67***	
Practical (learning) activities	0.91	0.53	36.61***	28.1
Constant	2.79		100.54***	
Engineering activities in school	0.25	0.07	4.03***	0.4
Constant	1.49		13.41***	
Encouragement by teacher	0.35	0.26	12.99***	6.8
Constant	0.76		8.18***	
Encouragement by parent	0.56	0.36	23.12***	12.9
Constant	1.47		26.86***	
Extracurricular engineering activities	0.72	0.42	27.31***	17.9
Constant	-0.35		-6.28***	
Motivation to engage in engineering activities	0.94	0.71	59.40***	49.9
Constant	0.11		0.97	
Perception of engineers	0.70	0.39	24.83***	15.3
Constant	1.24		19.06***	
Engineering efficacy	0.03	0.42	26.64***	17.7

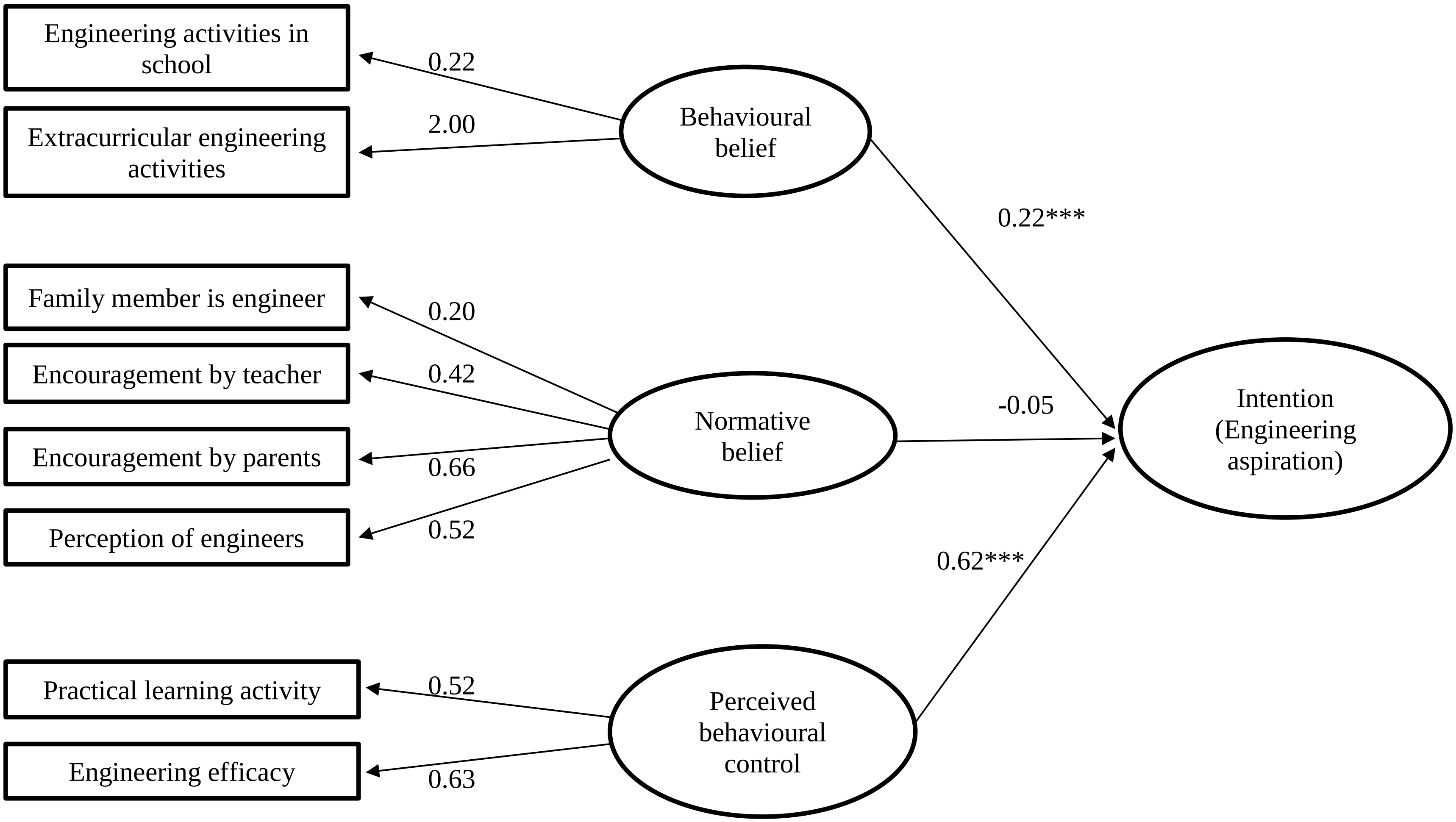
*** $p < .001$

Table 7: Comparisons of high-scoring versus mid- and low-scoring students for the Outcome factor in relation to demographic and Predictor Factors

Factor	Statistic	Associated Means
DEMOGRAPHIC		
Sex of student	$X^2(1) = 41.581$***	
School type – Sex	$X^2(2) = 18.292$***	
School type – Funding	$X^2(2) = 8.608$**	
Form	$X^2(2) = 7.595$*	
Place of Birth	$X^2(8) = 8.806$, NS	
Engineer in Family	$X^2(1) = 23.573$***	
PREDICTOR		
Practical (learning) activities	t = -20.816***	High = 4.60; Other = 3.75
Engineering activities in school	t = 3.871***	High = 1.68; Other = 1.75
Encouragement by teacher	t = -7.531***	High = 4.50; Other = 3.99
Encouragement by parent	t = -10.827***	High = 4.25; Other = 3.70
Extracurricular engineering activities	t = -11.402***	High = 2.47; Other = 1.83
Motivation to engage in engineering activities	t = -47.337***	High = 4.89; Other = 3.11
Perception of engineers	t = -15.903***	High = 4.63; Other = 3.97
Engineering efficacy	t = -17.420***	High = 66.89; Other = 50.76

*$p < .05$, **$p < .01$, *** $p < .001$

Figure 1: SEM of predictor factors displayed within TPB model and variance in relation to outcome (Engineering aspiration)



*p<0.05; **p<0.01; ***p<0.001
Total variance explained: 40%

	Chi Square (df)	CMIN/df	CFI	RMSEA
Model fit	341.65 (22)	15.53	0.95	0.05