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Students' engineering experience and aspirations within STEM education in Hong Kong secondary schools

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Abstract:

This study questions whether Hong Kong (HK) students' engineering aspirations are facilitated within their secondary school STEM curriculum or elsewhere. HK students perform strongly on international science and mathematics assessments, although its economy is reliant on a dwindling number of engineers. We consider STEM education metaphors, recent government attempts to improve STEM education and lack of Asian STEM literature. A representative twenty-four students (sex, age, secondary school type) were interviewed to elicit school/home e/STM (engineering within/STM subjects) experiences and aspirations. Thematic content analyses found: e/STM aspirations most susceptible to (pathway-based) home and cultural inequalities; younger students excluded from engineering interests; and, inhibiting in-school activities/pedagogies. Within this high-performing Asian society, inhibitors to engineering engagement were similar to current Western findings.

Key Words: Student aspirations, Engineering education, Secondary Schools, Hong Kong

1. Introduction:

The encouragement of students' engineering aspirations takes place in complex economic, social and role contexts. Of late, these contexts have been described using conceptual metaphors such as 'pipelines', 'pathways' and 'ecosystems' (Lee, 2019). According to Lee, these conceptual metaphors enable us to theorize what we mean by participation in engineering, which will potentially shape the forms of engineering research, practice and policies we pursue. In a 'pipeline', engineering participation is understood as passive, 'and progress is longitudinal as people are acted upon by the system flowing through the pipe without individual agency'. In contrast, participation in a 'pathway' is often active as people act upon the system traveling along a trail. Participation in 'ecosystems' is also active, but the progress is 'localized as people engage with others and experience specific environments' (Lee, 2019, p.9). For example, school and home/community are the most likely aspects of an ecosystem within which appreciation of STEM (science, technology, engineering, mathematics) subjects is developed, leading to student STEM career aspirations. This opens pathways/options for students to navigate the ecosystem, although curricular planning often perceives STEM aspiration as a pipeline where students progress via pre-structured courses and examinations.

Borrowing the 3 metaphors mentioned above, this study considers aspirational contradictions found within the STEM education literature - focusing on e/STM (engineering within/Science, Technology, Mathematics) and Hong Kong (HK) secondary school students' experiences; an important but underrepresented aspect of STEM (Holman, 2007; Katehi, Pearson and Feder, 2009); we also provide an Asian view within a predominantly Western literature.

Based on in-depth interviews with 24 secondary school students in Hong Kong, the study reveals that students' engineering aspirations were largely supported via personal pathways (e.g., experience offered by family and friends) rather than the school-based ecosystem. Compared to seniors, junior secondary school students tended to have limited access to engineering courses and gain less school support for engineering. School types are also found influential in male/female students' e/STM experience. e/STM efficacy was more likely to be developed outside of school, but lack continuity or direction within schools. Although it is too early to draw conclusions regarding the effectiveness of Hong Kong government's e/STM education reform, the study shows that traditional subject and pedagogic approaches still play a main role in students' e/STM experience.

2. General background:

The literature acknowledges an increasing need for students to take-up STEM careers while only a limited number of students have STEM aspirations (OECD, 2011; Osborne, Simon and Collins, 2003). This is especially strong with regard to engineering (Borrego and Bernhard, 2011; Maltese and Tai, 2011); often referred to as the hidden 'E' or STeM in schooling contexts (or e/STM). The literature further notes that STEM ecosystem educational opportunities are inclusively open to all students (La Force et al., 2016; Salome and Kling, 2017) but fail to attract females and ethnic minorities, and focus on high mathematics/science achievers (Wang, 2013).

The promotion of STEM as a 'pipeline' assumes that exposure to school/curricular-based STEM experiences will encourage and support students' positive aspirations (Lee, 2019). If the pipeline is successful, it will provide the personnel required for a region's economic/development needs (Osborne et al., 2003; Silim and Crosse, 2014). Yet, hand-in-hand with the pipeline is the concept of 'leakage' (La Force et al., 2016) wherein initial positive attitudes and exposure to STEM school experiences are not represented in the number of students aspiring to a STEM career(Kutnick, Chan, Chan, Good, Lee and Lai, 2018) leaving potential student aspirants to rely on home-based STEM/Science/Engineering capital (ASPIRES, 2013).

One of the reasons that schools play a limited role in promoting engineering aspirations is the limited number of courses/teaching-time given to engineering within the STEM curriculum. Characteristic of both Western and Asian school curricula, engineering is only introduced as an option in the upper years of secondary school (Katehi et al., 2009; Kutnick et al., 2018). In Hong Kong, likewise, engineering courses are not available for secondary school students in junior years and not compulsory for senior secondary school students. Engineering may be introduced within other STM (Science, Technology, Mathematics) curricula, but it is likely that teachers making these introductions will have little engineering knowledge, resources or engaging pedagogic approaches (Holman, 2007; Katehi et al., 2009; Nathan, Tran, Atwood, Prevost and Phelps, 2010). On this basis we use 'e/STM' to represent the way that engineering is approached in most secondary schools and acknowledge potential family, peers and media influences on e/STM aspiration (ETB, 2005).

2.1. Why focus on Hong Kong and its e/STM context?:

The importance of STEM education has been recognized in China (Zhu and Jesiek, 2014), with separate STM curricula within primary and secondary schools (Gao, 2013). Even with a strong distinction between post-industrial HK and the industrializing Mainland (Wei, 2005) none of these regions include engineering as a formal subject until upper secondary school. Pedagogic/teaching approaches across the regions have been characterized within a Confucian Heritage Culture (CHC; Biggs, 1996) although recent recommendations have encouraged greater student engagement (CDCHK, 2001; MoE China, 2001) in STM subjects. Further, students in HK and some Mainland regions have shown consistently high scores in international assessments of mathematics, science, yet these scores are not closely associated with positive attitudes to STM subjects (Martin et al., 2012; OECD, 2011, 2019). Especially in HK there has been a decline in number of students applying for university-based engineering degrees (Kutnick et al., 2018) although STEM subject numbers have been held at a constant level by the intake of a substantial number (25+%) of Mainland and international students (EDB, 2019).

Currently, researchers/educators have only limited information as to why students may aspire to STEM careers in Asia/HK. As of 2020, very few STEM education studies have been undertaken in Asian countries. Lee, Chai and Hong's (2019) international review of STEM education studies between 2013/7 found: 65% were undertaken in the USA while only 8.5% were undertaken in Asian countries; with few studies focused on engineering and only one (intervention) study focused on engineering design in HK (Lou, Chou, Shih and Chung, 2017). These statistics may seem odd when juxtaposed to the approximate 20+% of Asian students studying university-based STEM subjects (Kennedy and Odell, 2014).

With a particular focus on e/STM, HK is in a state of transition. Engineering in the 20th century was associated with manufacturing/trading of resources. The 21st century saw a transition to trading, civil engineering and financial engineering (Wei, 2005) where parents can play a limited role in providing experience and support for these newer applications. Only recently has the HK government realized that students have very low exposure to engineering topics within their curriculum (EDB, 2014) and started to make efforts to enhance the e/STM curriculum (CDCHK, 2015). The Education Bureau (EDBHK) has further promoted STEM education in schools via efforts to 'renew and enrich' its STM curriculum, identifying Key Learning Activities, providing professional development for curriculum leaders and providing schools with a (one-off) STEM grant. This report and its follow-up (CDCHK, 2016) rarely mentions 'engineering', identifying STEM enhancement within traditional STM curriculum areas. Early critical assessments of these efforts find: a recent HK-based study (Geng, Jong and Chai, 2019) focused on school teachers' concerns about STEM education (finding that less than 6% of teachers felt well prepared for STEM education); and Chan's (2019) and Tang's (2019) concerns over short-term funding and limited professional development making the reforms unlikely to achieve long-term goals.

3. **Some Characteristic Contradictions within the e/STM literature**:

The dearth of HK/Asian information on e/STM education justifies further study into students' engineering aspirations. Before this can take place, it would be beneficial to consider key points in the Western-based literature – such that themes/questions to be asked of students can be identified. A thematic literature review was conducted to address the question 'what affect students' engineering aspirations', which also guided the search and selection of articles. Inclusion criteria were: peer-reviewed journal papers on factors affecting students' engineering aspirations, published in English between 1990 and 2019. The corpus of data was drawn from keyword searches (e.g., ‘student engineering aspirations’, ‘engineering education’) in a range of recognised databases such as ERIC, British Education Index, and ProQuest and engineering education journals such as Journal of Engineering Education and the European Journal of Engineering Education. It should be noted that this is not a review paper, and the purpose of this review is to locate possible themes rather than providing exhaustive results. This review of e/STM literature has identified a number of contradictions; we focus on three (and methodological concerns) that may affect students’ engineering aspirations:

3.1. Interest in engineering:

Industrializing and post-industrial regions worldwide have realized an increasing need for more individuals trained and able to use e/STM skills (King, 2008; Kutnick et al., 2018; Maltese and Tai, 2011; OECD, 2011; Wang and Degol, 2013). Schools and STM curriculum identify the main (ecosystematic) vehicle to encourage students’ interests and aspirations; students receiving compulsory education are taught science, mathematics and computers/technology throughout the majority of their years in secondary school (Gao, 2013; Katehi et al., 2009). Increased ‘demand’ for e/STM appears to assume that students following their regional/national curricula will be exposed to information and practices that stimulate their interest/aspirations – although there is only weak evidence for this relationship (de Zilva, Vu, Newell and Pearson, 2013).

Rather than the ecosystem, the literature draws upon students’ personal pathways and social contexts to explain why only some have aspired to study/seek careers in STEM (Capobianca, French and Diefes-Dux, 2012; Godwin, Potvin and Hazari, 2014). Personal pathways may be affected by: age – where positive e/STM attitudes characterize students in the early years of secondary schooling but do not introduce relevant courses or advice until the upper years of schooling (Maltese and Tai, 2011; Osborne and Archer, 2007; Sohn and Ju, 2010; Unfried, Faber and Wiebe, 2014); sex and ethnicity – where girls and ethnic minorities are less attracted to STEM (Wand, 2013). e/STM social support is mainly provided by knowledgeable parents/relatives and peers (ETB, 2005, Godwin et al., 2014; Wang, 2013) rather than teachers (Nathan et al. 2010) – leaving student aspiration dependent on STEM capital (ASPIRES, 2013) to which only a minority have access (Katehi et al., 2009).

3.2. Catering for e/STM in schools:

Understanding of how/why students take-on e/STM aspirations often focuses on identity (Eccles and Wigfield, 2002)/social-cognitive career (Connelly and Simon, 2017) theories affecting individual attitudes. These theories underlie most intervention studies to promote positive STEM attitudes (Chittum, Jones, Akalin and Schram, 2017) and have a low correlation with developing career aspirations (Aschbacher, Li and Roth, 2010). These studies contrast with 'planned behaviour' that draws on efficacy contextualized within subject domains (Ajzen, 1991); and associated interventions show a much stronger correlation between efficacy and aspiration (Kutnick et al., 2018).

Further, the expectation that high achievement within STM subjects will lead to enhanced aspiration via motivation and persistence (Maltese and Tai, 2011) contrasts with findings that high achieving secondary school students tend to have poor STM attitudes (Martin, Mullis, Foy, and Stanco, 2012) and low STM achievers are likely to become discouraged in a competitive STM classroom atmosphere (Aschbacher et al., 2010, Wang, 2013). Achievement also exacerbates a problem of inclusion – all students are expected to study STM subjects while students know that only an elite group is likely to succeed (La Force et al., 2016; Salome and Kling, 2017).

3.3. Pedagogic contradictions:

Students are likely to base their STM attitudes on how subjects are taught (Katehi et al., 2009; Maltese and Tai, 2011). Traditionally taught approaches to the e/STM curriculum, subject-based teaching and extra-curricular activities (Osborne et al., 2003) may not be adequate to stimulate student aspirations (Brophy, Klein, Portsmore and Rogers, 2008; Nathan et al., 2010) as they focus on knowledge acquisition and attitude change rather than efficacy. Supporting e/STM aspirations must overcome contradictions between: (1) meaningful and relevant real-life e/STM topics are not often presented in curricular experience (Aschbacher et al., 2010; Osborne et al., 2003); (2) theory-dominated science/mathematics teaching (Lyons, 2006) and e/STM topics (Chittum, 2017; La Force et al., 2016; Wang and Degol, 2013) contrast with student desire for active, 'hands-on' learning activities (Katehi et al., 2009); and (3) engineering may need to be accorded subject/domain specificity early in schooling if an efficacy-based pedagogy to be effective (from Ajzen, 1991; Bandura, 1997).

3.4. Methodological limitations in recent studies of e/STM aspirations:

Methodological approaches of student aspiration studies often constrain what can be learnt and generalized. Age at which aspirations are likely to be made has been identified within the early years of secondary schooling (Osborne and Archer, 2007; Sohn and Ju, 2010; Unfried et al., 2014), yet many studies draw upon reflections from higher education students who have (already) succeeded in the STEM pipeline (for example Godwin et al., 2014). Quantitative approaches often support a particular theoretical orientation towards STEM aspirations (e.g. identity theory/social cognitive career theory; Connelly and Simon, 2017; Wang and Degol, 2013) rather than seeking in-depth qualitative understanding of student experiences (Kellam and Cirell, 2018). Few quantitative studies have attempted to provide representative, stratified samples (Aschbacher et al., 2010; Borrego and Bernhard, 2011) and predominantly Western samples offer limited insight into Asian and other cultures (Lee, Chai and Hong, 2019). Existing qualitative studies, similarly, tend to focus on particular cases and small-scale interventions, providing little insight into representativeness.

3.5. Problem statement:

This study acknowledges the dearth of Asian STEM studies and focuses on HK secondary school students' experience of e/STM. Students' school-based exposure to engineering is likely to be limited to a few specialized courses in upper secondary school, integration within STM subjects and extracurricular clubs/competitions; although there have been recent recommendations to improve school-based STM experience. We may expect that aspiration is affected at ecosystemic levels of curriculum and school but pipeline or pathways have not yet been explored. Through an interview-based study of a representative sample of HK secondary school students, this study seeks the following information:

1. What best describes students' engineering aspirations in terms of ecosystem, pipeline and pathway?

2. How are engineering aspirations affected by school/other experiences, engineering interests and pedagogies?

3. What insight can these students provide regarding e/STM reforms in the school system?

4. Method:

The research problem was approached with the requirements to be representative (by age/sex of students, school type/location in HK) while exploring for a depth of e/STM experience/aspirations information. A predominantly qualitative approach was drawn upon (Cohen, Manion and Morrison, 2011; Kellam and Cirell, 2018); using exploratory, semi-structured interviews. Prior to establishing the sample and general interview questions, we: 1) reviewed the HK curriculum and associated documents to ascertain the school-based ecosystem for e/STM; 2) conducted open-ended interviews with a limited range of students and teachers concerning their e/STM experience (pre-piloting); allowing 3) development of interview questions and piloting with a sample of secondary school students. Developed questions included: interest in engineering; school-based courses/experience; engineering activities; pedagogic aspects of engineering education; and impact on engineering aspirations. Six government-funded, representative schools (by educational district, vocational/comprehensive, and single/mixed sex, see Appendix 1) were identified and approached for participation. Each student was seen as an individual case although the exploratory nature of the study endeavoured to draw common threads of experience from the interviews (Walker, 1993).

4.1. Sample and ethical approval:

Table 1 identifies that the sample represented HK secondary school types at lower-school (S1-2), middle-school (S3-4) and upper-school (S5-6) levels. Upon ethical approval by the researchers' institution, consent (including the right to withdraw) for participation in the study was agreed with schools, parents and students. To ensure representativeness of the sample, researchers planned to interview four randomly selected students from each school with school subsamples including males and females (excluding the single-sex schools) from three age levels. Twenty-four students were interviewed. All schools and students were anonymized before analysis.

TABLE 1 ABOUT HERE

4.2. Procedure:

During pre-pilot/pilot stages, interviewers met to ensure veracity and meaningfulness of questions. The pilot and formal interview questions used in this study can be found in the Supplementary Materials for this paper. Interviews were conducted after school hours between June and July. All interviews lasted around one hour each and took place in unused classrooms, where distractions were unlikely to occur. Students were interviewed by the authors or research assistants of this research project. We are aware that our identity as university researchers may influence students' responses to the questions; therefore, students were informed and reassured multiple times that their answers would not have any impact on their school performance assessment and would remain confidential. Students were offered interviews in Cantonese or English and digitally recorded. Recordings were transcribed and translated to English (with random verification of translation by a second Cantonese-to-English translator).

4.3. Data analysis:

Analysis of interview data used a thematic approach (Braun and Clarke, 2006; Cohen, Manion and Morrison, 2011) and followed stages recommended by Denscombe (1998) and Miles and Huberman (1994), allowing semantically meaningful themes to be identified along with various associated topics aligned to each theme. Themes included: school-based courses/experience/activities; interest in engineering; pedagogic aspects of engineering education; and impact on aspirations. Within each theme a range of responses, grounded in student experience identified semantic content items. Content analyses were then reviewed for range and typicality of concepts (Walker, 1993). A randomly drawn (20%) of interview responses were further analysed for verification by a second analyst – and any coding discrepancies were discussed/resolved between analysts (allowing a reflective re-reading/coding of interviews). Little attempt was made to quantify these analyses although researchers maintained an awareness of age and sex of student, and type of school attended. When at least a third or half of the students identified the same theme, we refer to 'many' and 'most' students responding respectively.

5. Themes and Insights Provided by the students:

In undertaking the thematic analysis we provide: a school-based (ecosystemic) background of courses and student comments; a general (pathway) consideration of students' concepts of engineers and reasons for becoming interested in engineering; and pedagogic activities which might align with aspiration metaphors.

5.1. School-based courses/experience:

5.1.1. Courses Currently Studying

Under the Curriculum Reform (CDCHK 2002), Key Learning Areas (KLAs) were introduced to the school curriculum to provide "a knowledge context for the development and application of both generic skills… and subject-specific skills" (CDCHK, 2002 p.3). Within this framework, technology education (TE), mathematics and science were among the eight KLAs that aimed to equip students "with the essential knowledge contexts that are related to the improvement of everyday living, and the social and economic development" (CDCHK, 2002 p.5). With particular regard to STEM education, both the curriculum and KLAs were 'reviewed and enriched' to enhance teachers' professional development and allow students to become life-long learners of science and technology' (EDB, 2016).

With regard to e/STM subjects, all students interviewed acknowledged they had been taught science, mathematics and technology (mainly computer-based); yet, 'e' (engineering) courses/instruction were not evident and there was a disconnect between school-based courses and the potential of choosing engineering as a university major/career. All of the junior secondary students (S1-3) interviewed were studying TE courses (Computer Literacy and Home Economics/Technology and Living), except for: School 5 - S2 students also studied Visual Arts; and younger students in Schools 3 and 5 (female-only and coeducational schools) studied Fashion Design. Among the senior students (S4-6), only one S4 student from School 3 studied the TE course of Business, Accounting and Financial Studies, with no students indicating they were taking any engineering courses. Nevertheless, when senior students were asked if they were taking courses that steered them towards engineering, the most frequently named courses were elective sciences such as physics, chemistry and biology. These courses were also identified when students in S2 (coeducational) were asked if they had thought about what subjects they would like to take when they entered senior secondary. One of the main reasons for their preference in science subjects was the perception that these courses were "easier than" and "not as boring as" arts-based courses. Some students indicated that science courses helped "train their minds" to solve problems and that "science teaches us something that is related to our living" (S2 Student, School 4). Students also noted that to become an engineer it would be necessary to take science courses, as they perceived that "engineers need to be good at mathematics and science subjects".

S2 students were aware that engineering courses were not available even if they were interested. They reckoned the school or course administrators considered such courses to be "too difficult for young students to understand". One of the students suggested "I think they can teach something basic about engineering then we won't need to learn these things in the S3 or 4, then I would have the basic knowledge about engineering" (S2 Student 1, School 4).

Senior students were further probed as to whether they would consider pursuing a degree in university; only one student did not wish to go to university. Although these students did not take any engineering courses at school, many stated they would like to choose engineering-related subjects (such as civil, computer, electronic and mechanical engineering) upon entering university. The school-based (curricular) ecosystem appeared to have little effect on engineering pipeline aspirations, suggesting that personal pathways were dependent on out-of-school, home-based experiences.

5.1.2 Engineering related activities organized by the school

Very few students indicated their participation in engineering-related activities in school, citing either there were none available or they were not aware such activities were available in their schools. The most active (engineering-oriented) school was the vocational school. With the exception of School 4 (male-only), there were no engineering clubs in the schools (although some computer clubs existed). Of the few students who had participated in engineering-related activities, virtually all were in upper forms (one in S4 and two in S6). One of the S6 students attended Open Day activities organized by the Electronic and Engineering Society (School 4), while other S6 students participated in activities outside school (a flight workshop organized by a local university). One S4 student participated in the International Chemistry Olympics. Students attending these activities stated that they participated "out of interest", with little influence from peers or teachers. Some students explained their lack of participation due to "having to juggle exams and school work load".

Similar to remarks on the unavailability of engineering courses to younger students, one S4 student noted he would like to participate in engineering-related activities but "… did not have many opportunities. Not in junior or senior forms" (S4 Student 1, School 6). Younger students often stated that even if engineering-related activities were available in their school, most of them would be available to higher forms only.

The school with the highest participation in extra-curricular engineering-related activities was the vocational school (School 1). All students interviewed in this school had participated in engineering-related extracurricular activities, with participation in competitions (Hong Kong FFL Robotics Tournament, Canadian Computing Competition, International Olympiad in Informatics) and were offered an in-school technology competition and various science-oriented societies. In addition to competitions, a student-parent field trip was organized to visit Shenzhen (Mainland China) for S1 students (to learn how to construct a motorcycle using straws). The school organized workshops (in co-operation with the Robot Institute of Hong Kong) in which lecturers from local universities introduced science projects (e.g. how to use a computer software programme, how to construct a solar car or water rocket). In turn, some students acted as 'ambassadors' and taught what they had learnt to younger primary school pupils. When asked if participation in such activities was compulsory or voluntary, students indicated all were voluntary and they opted to participate because they were interested in learning more about engineering.

5.1.3. How engineering is supported in school

Students from different year groups did not agree on the extent of support their school provided in terms of encouraging engineering in school. Their experience differentiated between school types (especially between vocational and female-only), age of students and teacher commitment to engineering. S2 students from School 3 mentioned their school encouraged students to participate in competitions, however only senior forms were eligible and they did not get to know about the activity until "after someone won a prize". S4 students (School 3) recalled no encouragement from school, whereas S6 students responded there was low-level support - mostly in the form of recommendations "to participate in competitions outside school" for interested students. Even though there was an electronic and engineering club in School 4, this activity was targeted at senior form students only; these S6 students noted the club organized a variety of activities (such as competitions, teaching how to construct motor cars) which raised their interests. There were three physics teachers who were advisors for the club, "providing support for the senior science-oriented students who joined the club". In comparison, School 1 provided support for students of all ages, ranging from competitions organized by in-school societies (e.g. technology activities by Computer Club and an annual competition among the 4 science societies in school) as well as outside organizations (e.g. Water Rocket Competition).

When asked why their school were not keen about engineering, students identified that teachers who taught subjects other than engineering might lack the knowledge/experience outside of their expertise and were incapable/not enthusiastic in promoting engineering. Others considered that as there were no engineering courses offered in their school, there would be less concern from teachers or school to encourage or support students to get to know more about this area. Unlike the S2 and S6 students from the same school, S4 students from School 3 raised the point that their girls-only school provided limited incentive to promote engineering as "the common perception is that young people cannot tolerate hardship, and engineering seems to be very hard and labour intensive" (S4 Student 1).

5.1.4. Students' perceptions of engineering educators

Students were asked to recall the first time they came across someone who had taught them about engineering through activities either in schools, extra-curricular activities or at home. Recollections showed a divergence between informal/family support, biases towards traditional curriculum subjects and gender stereotypes. Students whose family members/relatives were engineers were more inclined to cite these as the person who introduced engineering to them. Primary school mathematics teachers and secondary school science teachers were mentioned infrequently. Friends who were currently studying engineering in university also provided an introduction to engineering for some older students.

Regardless of gender or age, students were prone to describe engineering educators as "people who run engineering activities in schools" (such as mathematics or science teachers), with the perception that one has to be "good in mathematics or science to excel in engineering". Few students were aware of teachers who had worked in engineering-related jobs or possessed a background knowledge in engineering. The majority of students considered there was no difference in having either a male or female take-up the role in running engineering activities in schools. A small number of students (3 females and 2 males), though, acknowledged that these teachers were likely to be males as: they perceived males to be better at science and mathematics than females (S2 Students 1 & 2, School 5) saying that: "engineering is a labour intensive job so males are more physically equipped to handle (the job)"; and "males are more likely to suit the image of engineering" (S4 Students 1 & 2, School 6). S6 girls from School 3 pondered the reason why it would be more likely to be a male teacher responsible for running engineering activities as "there are very few girls choosing engineering in some co-ed schools, and there are also very few girls in the science stream class" (S6 Student 2). On the other hand, "there are more girls choosing engineering in girls-only schools because there is less gender stereotyping" (S6 Student 1). These students identified that female students would face less pressure if they choose engineering in girls-only schools as "there were more people of the same sex to discuss their choice".

Overall, students identified both formal and informal engineering educators – but few of the educators (except for parents/relatives) had an effect on student attitudes or expectations of becoming an engineer. Students' views varied widely by age level, types of opportunities offered and the context within which the engineering opportunities were offered. In particular, differences in school-type showed that students were offered more engineering experience in the vocational school than the general schools. And, girls within the girl-only school felt more involved in their engineering experience. Thus, engineering experience was affected differentially at ecosystem level (type of school attended) and pathway explanations were promoted by engineering 'capital' engendered in and around the home.

5.2. Interest in engineering:

5.2.1. Impression of an engineer

Students became interested in engineering at different ages and for a variety of reasons. Their pathways, though, were often enhanced by relative and peers or inhibited by late onset of engineering activities/courses in school. When asked 'what an engineer does', responses drew upon both innovative and technical roles in engineering. This understanding came mainly from their interaction and experiences with engineers and provides some insight into engineering pathways. Regardless of age, frequently cited aspects were related to civil engineers: supervising and surveying construction sites, drafting/designing building plans and infrastructure. Other role responses included computer engineers (ex. designing programmes) and mechanical work (repairing machines and equipment). Understanding of engineering roles were broader when a parent/relative/friend was an engineer. One student, whose father was an engineer, not only described "the role of (an) engineer is to examine things and to build things" but went further to elaborate on the social responsibilities "…like for the construction of the whole society. It is very crucial for the growth of the economy." (S4 Student 1, School 4).

How students got to know about engineers differed with respect to whether students had relatives/friends in the field. For students with parents/relatives/friends in engineering, their impression of an engineer came from watching or listening to talk about their work and study experiences. For those with no engineering relatives/friends, television programmes provided most of their information - especially among younger students. Senior students accessed the internet as a popular option, either searching for information on specific topics or learning through websites of local universities. A few senior students gained their knowledge through the participation in an engineering club or activity organized by the career section of their schools. Having the opportunity to participate in a competition (e.g. HK Robotics

Tournament) was another reason to become interested in engineering (School 1). Schools, again, appeared to play a limited role in inspiring engineering interest – no formal curricula were mentioned although extra-curricular activities were identified.

5.2.2. Reasons for getting interested in engineering

The most common reason for becoming interested in engineering was, as might be expected, a personal pathway such as having relatives/friends studying/working in engineering. For these students the experiences and stories from their relatives/friends aroused their curiosity. Onset of student interest ranged from very young to secondary school entry. The few students who replied that they did not become interested until after entering secondary school, identified that they did not make up their mind until after having studied a TE course, and were mostly found in senior forms.

Being interested in a particular occupation also served to be a strong motivation for the students. Two students (S4) expressed their desire to become a pilot, while two others (S2) indicated their fascination with design of roads and buildings. For these students, their quest for learning more about engineering started when they were in primary school - but they received little information about these occupations from their secondary schools. One S4 student from School 3 (female-only) indicated media reporting on females working in engineering stimulated her interest along with the fact that “my cousin is an engineer”. These aspects changed her stereotype that “only males can become engineers”.

5.2.3 Types of engineering activities engaged

Students were encouraged to talk about informal and formal engineering activities. Their comments emphasized a ‘hands-on’/informal approach as opposed to knowledge-based engagement. Frequently named activities included “built something from a kit” and “taken something apart to see how it works”. Only a few students mentioned subject-related “studied engineering problems in Maths classes” or “met a male engineer” during an extra-curricular visit. Within school, younger students identified they had “done an engineering activity in a Design and Technology lesson”. S4 and S6 students reported they “studied engineering problems in other parts of my schoolwork” in science and mathematics lessons, and some had “heard a talk by an engineer”, “visited a university where students study engineering” or “visited an engineering project”. While most students noted they had “met a male engineer”, only 6 students had “met a female engineer”.

When probed to reflect on why they engaged in engineering activities, students were most likely to have used their own initiative and worked on their own when outside-of-class (at home building/fixing something or taking something apart). Students tended to work on these projects “on their own” and only called upon help from engineer parents or friends when they encountered problems they could not solve. In contrast, school-based projects (when they occurred) were organized and supervised by teachers.

5.3. Perceptions of e/STM pedagogy:

5.3.1 Learning through engineering related activities

Students were asked to recall an activity in which they learnt something related to engineering; these recollections expand upon informal learning opportunities and raise a number of pedagogic concerns. Most students could not recall specific, school-based activities and claimed they learnt by themselves (supported by family engineering capital pathways). Nevertheless, for the few who did recall a specific learning event in schools, younger students identified field trips or visits to science exhibitions and famous buildings. None of these students remembered learning anything of particular relevance to engineering and some reasoned they were “too young to understand”. Older students recalled activities in their senior years: an in-school engineering open day; science exhibitions; competitions; talks organized by a local university. This ‘engineering-learning’ was linked to exploring how things worked; whether applied to practical design or engineering concepts. Informally (see section 2.3), most of these students’ pathways were guided by home-based experiences of hands-on ‘building/taking apart’ things.

We speculatively consider here capital-based differences between e/STM experiences at school and home may relate to the difference between recall and reflection (Moon, 1999). After participating in a school-based engineering activity, the majority of students were not asked to think about/reflect upon what they had done or learnt. After a lesson or during revision they noted they would make an effort to ‘recall’ the outcome rather than explain why that outcome occurred. Students tended not to share/discuss why that outcome occurred among themselves. Likewise, few students would write-up an account after attending an engineering related activity unless they were requested by their teachers. It appeared that neither within-school nor school-based extracurricular activities actually encouraged students to reflect upon their engineering actions – and opportunities to gain a greater depth of knowledge as to how these experiences would lead to a career in engineering were limited.

On the other hand, students who chose to informally talk to someone about these activities were most likely to do so with parents and friends. This talk was more than recall and tended to seek explanations of their activities and provided opportunities to reflect on experience/capital gained.

5.4. Impact of the Engineering Related Activities:

5.4.1 Career in engineering

Many students identified engineering as a possible career and understood progression towards a career relied on their educational background. This identification, though, was mainly based on out-of-school personnel and activities. While younger students received no direct teaching/experience in school concerning engineering, about half of them were interested in pursuing engineering as a career. Six of the seven S4 students gave the same response. Of the five S5/6 students, students from the girls-only school were interested in an engineering career while the students from the boys-only were not interested. One S3 and one S5 student from the vocational school identified that they would consider engineering for a career/study. Regardless of age, aspiring students identified two main reasons that influenced their decision: (1) having parents/relatives as an engineer or friends who are studying engineering in university; these people served as models/sources of information (e.g. “Because my dad is an engineer and I think what he does in his job is admirable.” (S2 Student, School 5); or (2) having a hobby or dream job which required the knowledge of engineering. More specifically, an S5 student from School 1 pointed out that his interest stemmed from the opportunity to participate in an engineering competition during a lower year - which paved the way to his decision to pursue a career in engineering.

Those students interested in engineering careers claimed they knew the route (mainly an academic route) to become an engineer. Yet, there were distinct differences in how well informed the students were in terms of the courses they needed to take. Most students acknowledged mathematics- and science-related courses in secondary school as a necessary prerequisite to qualify for university engineering courses. Younger students were less-well informed except for those whose friends or relatives were already in the field. Senior students were more likely to search for this information themselves (browsing internet websites or visiting universities) rather than relying on school-based careers advice.

All students considered “getting a degree” as the only route to become an engineer, and none of them were aware of the possibility of pursuing engineering via a vocational/apprenticeship route. One S3 student from School 1 questioned whether one can become an engineer without entering university. Even with the interviewer elaborating on the possibility of obtaining an engineering qualification via vocational institutes, the student remained doubtful and remarked that “it would only be useful if the study in vocational institutes could enable my transfer to university to obtain a degree”.

Students who were not keen on becoming an engineer cited being interested in other areas of study most often. Students who indicated an interest in engineering earlier in the interview but chose not to pursue this career cited concerns about less desirable grades (they) received in science courses. Not having the opportunity to know more about engineering at an earlier age also discouraged students against exploring the field. In particular, one student remarked, “Now I would not (consider pursuing a career in engineering). If I got to know about (engineering) earlier I would.” (S4 Student, School 3). Despite students from School 3 and School 5 mentioning a career counselling team, if they needed guidance junior form students from S2 or S4 were neither aware nor motivated to seek advice. Most students noted that guidance would be available to senior forms only or that they felt “left out” because of their young age. Even in the vocational school the youngest S1 students thought it was too early for them to consider their future career/studies. Older students were hesitant in their decision to pursue an engineering career, with one stating “being interested in studying engineering might not indicate the same interest in pursuing an engineering career”.

5.4.2 Opportunity to act as an engineer

To investigate whether students had an opportunity to act as an engineer (in an efficacious sense), they were asked to describe if they had ever built, created, maintained or fixed something at any occasion. Most students reported that they had engaged in the above activities. And, most of the activities were undertaken outside of the classroom and included hobbies (e.g. building models) and fixing household items or furniture at home. Only a few students recalled school-related engineering activities (building things in TE courses, participating in competitions). Home-based activities were most likely to be performed alone and students used their own initiative during the activity; offering opportunities to develop their engineering efficacy. Even when they encountered difficulty during the task, they preferred to solve the problem on their own before asking for help from parents or friends.

Few within-school activities/engineering engagements offered these efficacy opportunities even within schools that had technology-oriented extracurricular clubs.

6. Discussion:

Interviews investigated HK students' e/STM experiences and questioned whether engineering aspirations were supported via ecosystem, pipeline or personal pathway. Questions focused on engineering experiences: (formal and extra-curricular) in schools; personal interests and opportunities; and underlying pedagogies. Overwhelmingly, students' engineering aspirations were based on personal pathways rather than recognizing ecosystemic development needs of HK or curriculum recommendations recently implemented by the HK Education Bureau. Although it is early days to comment on the effects of HK's STEM recommendations, it appears that a planned, progressive STEM curriculum (CDCHK, 2015) has had little effect on students' aspirations – especially compared to having parents/relatives as engineers, friends studying engineering or type of school attended. Discrepancies between the availability of engineering courses and extent of support from school for junior and senior forms were identified as within-school factors that restrained students from approaching engineering. Limited access to focused engineering activities was most cited by younger students for their lack of understanding or disinterest in getting to know more about engineering; although they all accessed basis technology courses. This lack of engineering opportunity for younger secondary school students has also been found internationally (Capobianco et al., 2012; Katehi et al., 2009), has not been compensated for via career counselling or access to real life (engineering-related) experiences (Maltese and Tai ,2011) and has discouraged expectations of further study/career (similar to Unfried et al., 2014) . The lack of opportunity within the HK STEM recommendations has been commented upon (Chan, 2019; Geng et al., 2019; Tang, 2019). Once students entered senior years, it would be likely that many would have developed an interest in other areas of study (see Holman, 2007).

e/STM experiences were also limited by type of school attended. Contrasts between male-/female-only schools showed that engineering interests of the girls were supported while the boys were not. Among the girls a number of contradictions arose. They received less pressure from stereotyping than co-educational schools and had positive attitudes towards engineering careers, but they also held the view that there was less incentive for their school to promote engineering; perceiving that engineering was a masculine, labour-intensive occupation.

Regardless of type of school or year of study, the stereotypical impression of engineering as male-dominant and requiring excellence in science and mathematics dominated perceptions (as elsewhere: Aschbacher et al., 2010; Hill, Corbett and St. Rose, 2010). These attributes may characterize the Confucian Heritage classrooms of HK (Biggs, 1996) and identify that proposed pedagogic reforms (to enhance student engagement in their learning, CDCHK, 2001; 2015) have not been effective to date (Chan, 2019).

Even though many students expressed an interest in engineering, when probed about their aspirations many responses showed a reluctance to consider engineering. One major obstacle was self-doubt that current grades would not be good enough to get a university place (in engineering). Other concerns included whether they could maintain their enthusiasm within higher education and career - as opposed to when engineering was only a hobby or a current project. This discontinuity between interest and aspiration appears to mirror the support that can potentially be offered by career counselling/range of engineering opportunities (clubs, etc.) and their relative lack of provision in schools. Further, students did not appear informed about distinctions between technical career and higher education study nor the evolving range of engineering opportunities (Bloomfield, 2017).

In terms of engineering-related activities, competitions and field trips were prominent in the pipeline of activities available in schools. These activities, while pedagogically engaging for students, were generally one-off and lacked a long-term commitment to development of e/STM efficacies/reflections (Ajzen, 1991). These findings may also indicate that STM reforms in HK (CDCHK 2015) were focused, in the main, on students' attitude change rather than competence/efficacy development. Even when some students recalled interests in engineering-related activities available in primary schools, there was little opportunity for these interests to make the transition into secondary schools.

When considering potential pathways to enhance engineering aspirations, students appeared most reliant on home/peer support and their own hobbies (building/taking apart objects) to develop early efficacies (Bandura, 1997; Maltese and Tai, 2011). This out-of-school support is likely to advance an 'elite' community with engineering 'capital' (from ASPIRES, 2013): those with an engineering background begetting engineering aspiration without broadening this experience to others.

With the above in mind, it is also possible to reflect on the possible contribution of STEM reforms recently implemented in HK. These reforms included enhancing student engagement, teachers' professional development, curriculum revision, one-off support funds and resource development and were similar to many reforms undertaken in Western countries. Early feedback from our students, teachers (Geng et al., 2019) and academics (Chan, 2019; Tang, 2019) have all commented: on the lack of engineering within STM reforms; greater need for professional development; competence orientations of students and teachers; and a need to move from short- to longer-term planning.

7. Conclusion and limitations of the study:

Student interviews took place within the highly competitive- and high achievement-oriented region of Hong Kong. A number of traditional STEM aspects were already in place in HK to support student aspiration – strong, traditional, science and mathematics-oriented teaching, extracurricular opportunities and competitions, and a society with an evolving and increasing need for engineers at both technical and theoretical levels. Yet, this study bore out many of the contradictions that are found in the international/western-dominated literature. Students felt little connection to the educational system which, in theory, supported students' STEM developments within the curriculum (CDCHK, 2015). Rather, students' aspirations were largely supported at a personal level via experiences offered by family and friends. Small communities of e/STM practice (development of capital) were able to support the few students with this experience – and did not generalize to the wider student body. Schools appeared to offer little to promote enhancement of e/STM aspirations aside from the STM curriculum, clubs for older students and some competitions. e/STM efficacy appeared to be developed outside of school and did not have continuity or direction within schools. Thus, school-wide realization of the importance of STEM effected in government-based curriculum recommendations has yet to be taken-up. On the other hand, students in this study identified particular areas where opportunities offered by schools can be enhanced to expand e/STM aspirations (e.g. courses for younger students, a reconsideration of pedagogic approach to include efficacy-based learning and reflection and technical opportunities).

With regard to our research questions, we provide the following information. The school-based ecosystem was unlikely to promote students' engineering aspirations, where those most interested in engineering appeared to acquire this interest in out-of-school, personal pathways. Their aspirations drew upon a range of capital-based engagements and support that overcame age and gender biases through efficacious 'hands-on' activities. And, while it may be too early to ascertain whether the government's e/STM education reforms are likely to be effective, it appears that traditional subject and pedagogic approaches still characterize students' e/STM experience.

One major limitation of this study concerns its small sample size due to the amount of time and resource needed for in-depth interviews. We acknowledge that interviews with 24 students provide a limited picture of Hong Kong students' engineering aspirations and experiences, and it is difficult to draw general conclusions. However, considering that this is a pioneering study in engineering education, we target at facilitating understanding instead of generalising results. Moreover, our student sample is considered representative as it incorporates students from different school types (including general and vocational schools, co-education and male/female only schools), school years (including students from Year 1 to 6), regions (including schools from different regions in Hong Kong) and gender. For future research, it would be beneficial to scale-up the sample size to further explore effects of vocational education, substantiate differences within and between single-sex schools and co-educational schools and to gain more insight into engineering capital engendered at home/with peers. Further, as this study took place shortly after HK's realization of the importance of STEM education (CDCHK, 2015; 2016), it may be beneficial to ascertain whether a longer gestation period is required to bring about ecosystem developments at school and curriculum levels.

Conflict of Interest Statement:
On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Appendix 1: Summary of Sample

Characteristics	***N* (Students interviewed)**
SEX OF STUDENT:	
Male	13
Female	11
FORM (Year in school):	
S1 (12 years old)	2
S2 (13 years old)	8
S3 (14 years old)	2
S4 (15 years old)	7
S5 (16 years old)	2
S6 (17 years old)	3
SCHOOL	
Type:	
Coeducational (4 schools: *1*, *2*, *5*, *6*)	13
Male-only (1 school: *4*)	5
Female-only (1 school: *3*)	6
General/Vocational	
General (5 schools: *2*, *3*, *4*, *5*, *6*)	21
Vocational[1] (1 school: *1*)	3
Region:	
Hong Kong Island (1 school: *4*)	5
Kowloon (2 schools: *2*, *5*)	6
New Territories East (2 schools: *1*, *6*)	7
New Territories West (1 school: *3*)	6

[1] Vocational schools are now being phased out in the HK school system.