Embracing Ambiguity: Agile Insights for Sustainability in Engineering in Traditional Higher Education and in Technical and Vocational Education and Training

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Abstract.

Purpose:
Embracing reflective practice and retrospection, with a goal of identifying commonalities, this paper examines delivery of engineering subjects in both traditional higher education (THE) and technical and vocational education and training (TVET).

Design/methodology/approach:
Reflections on actions and autoethnography were employed to examine the teaching and learning experiences of three educators across two higher education (HE) institutions (HEIs), in the greater Chinese context. Literature reviews and historical contexts are outlined to support the approaches and insights identified.

Findings:
The paper presents a number of common characteristics and challenges identified across both THE and TVET. Drawing on the successful embrace of ambiguity and change in recent software engineering (SE) development paradigms, recommendations are then made for how the agile SE themes can be applied in a larger sense to address the wider challenges facing both THE and TVET.

Originality/value:
To the best of our knowledge, this is the first time engineering education has been examined and contrasted in the contexts of THE and TVET. The similarities and common challenges may represent a new focus for related work, and the presented insights, from agile methodologies in software engineering, represent a new perspective for viewing future HE and TVET sustainability.

Keywords: Higher Education (HE); Technical and Vocational Education and Training (TVET); Technology-enhanced Learning; Open and Flexible Learning; Open Educational Resources; Reflection.

1 Introduction

The importance and impact of reflective practice in education (Moon, 2013; Schön, 1987), especially in higher education (HE) (Towey et al., 2016; 2018), has been increasingly recognised. This paper reports on the application of reflective practice to examine the differences in how engineering (especially civil and software) is taught or learned in both traditional HE, and in technical and vocational education and training (TVET).

Our reflections involved not only examining our own experiences in the relevant educational context, but in at least one case, also included a short autoethnographic

journey into an author's time as student and educator. Ethnography involves field participation and engagement, using observation, in-depth interviews, and written accounts to observe social patterns (Gummensson, 1991). It aims to enable researchers to identify the "essence" of human experiences and to understand the "lived experiences" through extensive and prolonged engagement, to observe patterns and relationships of meaning (Moustakas, 1994 as quoted in Creswell, 2003 p.15). In contrast, but related, autoethnography is a type of research involving "self-observation and reflexive investigation in the context of ethnographic field work and writing" (Maréchal, 2009, p.43), and has also been used as a "rigorous approach and framework for reflection" (Towey, 2015, p.11).

Many recent innovations in teaching and learning have impacted on the perception and delivery of education. New technologies and approaches, including more open and flexible technology-enhanced learning (TEL) options such as massive open online courses (MOOCs) and other open educational resources (OERs), have led to advances in classroom practices and HE delivery. Some of these advances have had unintended (but welcome) consequences, including expanding the teaching and learning discussion in HE (Tait, 2018). Unfortunately, as well as their positive impact, some advances have also raised challenges and threats to both TVET and engineering in traditional HE (ETHE).

Although ETHE and TVET may not appear to have a lot in common, we have recently had opportunity to examine and reflect on both, within a Chinese context. Our selection of civil and software engineering to represent engineering in education reflects our professional contexts, and, while not necessarily representative of all engineering courses, they do both contain elements common to all. Thus, we anticipate that our examination and reflections should be of interest to all engineering educators. Our reflections led to identification of not only areas of overlap and parallels in terms of goals and curricula, but also of challenges common to both. We have also identified insights and approaches that may be applied to support the future of both.

The rest of this paper is laid out as follows: Section 2 presents the background, including the history of civil engineering (Section 2.1.1), software engineering (Section 2.1.2), and TVET (Section 2.2); the Chinese context of the authors is explained in Section 2.3. Section 3 examines some parallels between ETHE and TVET, including discussion of some of the most important challenges to both. Finally, Section 4 concludes the paper by returning to an earlier theme of agility, explaining how it could be employed by both ETHE and TVET to better position for a more sustainable future development.

2 Background

This section introduces the background and history of civil engineering, a very traditional engineering discipline, software engineering, a much more recent addition to the engineering family, and TVET. It also outlines the Chinese context of the authors.

2.1 Engineering in Traditional Higher Education (ETHE)

2.1.1 Civil Engineering

Civil engineering (CE) has a long history and can be first traced back to the Egyptian Heliopolitan high priest Imhotep, who is credited with building the first of the pyramids in Saqquara *circa* 2650 B.C. (Kirby et al., 1956); however, in spite of a number of historic CE achievements over the next 4400 years, no formal engineering education establishments existed prior to the 18th century. The establishment of the *Ecole Nationale des Ponts et Chausses* in 1747 represented the first known effort to comprehensively train engineers in science and engineering and led to the respected *Ecole Polytechnique* being founded in 1794. At this time, the importance of CE and its place in society were starting to gain recognition, but places for CE education were not yet commonly established; however, the US changed sentiment when George Washington noted its reliance on European (in particular French) engineers during the Revolutionary War (1775-1783) (Grayson, 1985). In 1802, the military academy at West Point was created, which closely followed a similar curriculum to the one established at *Ecole Polytechnique* (ASCE, 1972). In spite of these movements, it wasn't until 1845 that Union College in New York established a CE course, and not until 1847 that the first Ivy League university, Brown University, began to offer CE courses.

Between 1750 and 1850, industry was developing in Britain and the CE profession was emerging through necessity. However, developments remained the possession of reputable practitioners, and were not leading to the formation of educational establishments. Even one of the most iconic engineers of the period, Isambard Kingdom Brunel (1806–1859), was scornful of the teaching of theoretical engineering without application, explaining that "[a] few hours spent in a blacksmith's and wheelwright's shop will teach you more [about] practical mechanics" (Buchanan, 1985). In future years however, it became evident that the growing complexity of engineering necessitated the incorporation of scientific principles into CE education.

John Smeaton is credited as the first person to call himself a civil engineer (Denny, 2007), which later led the establishment of the CE profession and the Royal Society of Civil Engineers. The first courses dedicated to science and engineering didn't emerge in Britain until 1826, at University College, London, and 1828 in Kings College, London (Ashby, 1959). CE courses were not restricted to Europe and the US: the Meiji period in Japan gave rise to their first engineering college in 1873, later known as the Imperial College of Engineering. The college was run by a young Scotsman, Henry Dyer, who is credited with pioneering innovations that today might be known as summative assessments. Dyer took this knowledge home when he returned and used it to benefit British engineering education (Brock, 1981).

During this time, German engineering education was gaining recognition, and was not encumbered by the British nostalgia attached to historical engineering educational methods. Advanced institutes incorporating scientific rigour into the teaching of engineering were created, including the Technical Institute of Munich (1868) and Berline Technishce Hochschule (1879). By the end of the 19th century, Germany had 25,000 science and engineering students in universities (Roderick & Stephens, 1981);

the US had 10,000 students enrolled in engineering colleges and universities (Layton, 1986); Japan had over 240 technical schools and colleges (Lockwood, 1954), but the UK was languishing with only 3,000 enrolled students (Roderick & Stephens, 1981).

Advances were also made in the developing world. In 1947, when India gained independence from the UK, they only had 900 engineering graduates. A decade later this number had tripled (Kabir, 1956), and had hit 250,000 by the mid-1980s (Mohan, 1987). Similarly, after 1949, China saw great growth in the number of engineering students graduating from their educational system, with nearly one third of all graduates in the 1950s obtaining an engineering degree (Orleans, 1961).

What is evident throughout the history of engineering education is that the profession has sought to improve its reputation and incorporate scientific rigour and accountability into its practice. This has led to the creation of accrediting bodies who are able to review educational courses and verify that syllabi and teaching methods are appropriate for developing and maturing the next generation of engineers. One of the most famous accrediting bodies is the Institute of Civil Engineers (ICE), which was founded by Thomas Telford in 1818, and gained royal chartership in 1828 (ICE, 2018). An important excerpt from the charter reads (ICE, 2017, p.4):

> *[...] there should be ready means of ascertaining persons, who by proper training and experience, are qualified to carry out such works. It requires a broad understanding of scientific principles, a knowledge of materials and the art of analysis and synthesis. [...] A civil engineer is one who practices all or part of this art.*

The royal charter, and the ICE specifically, continues to influence CE education today. Modern, qualified civil engineers can be awarded the internationally recognised chartered status, and graduates from ICE-accredited courses can obtain credit towards fulfilling their lifelong development as Civil Engineers.

2.1.2 Software Engineering

For many people within the software community, the year 2018 marked the fiftieth anniversary of what is frequently cited as the birth of software engineering (SE): a NATO sponsored conference in Garmisch, Germany in 1968 (Naur & Randell, 1969). Although Margaret Hamilton is often credited with coining the term (Snyder & Henry, 2018), it was at the 1968 NATO conference that that the words “software” and “engineering” were paired for the first time in a deliberate call to practitioners to apply structured, rigorous “engineering” approaches to address the on-going software crisis. That crisis included software development running over schedule, over budget, and often producing low quality systems; or not producing a system at all (Charette, 2005). The cause of this crisis was famously described as follows in Dijkstra’s 1972 Turing Award lecture (Dijkstra, 1972, p.861):

> *“The major cause of the software crisis is that the machines have become several orders of magnitude more powerful! To put it quite bluntly: as long as there were no machines, programming was no problem at all; when we had a few weak computers, programming*

> *became a mild problem, and now we have gigantic computers, programming has become an equally gigantic problem."*

It was anticipated that applying the rigour and formal methodology of traditional engineering (such as CE) would make it possible to "design and implement the kind of systems that [were] straining our programming ability at the expense of only a few percent in man-years of what they cost us [then], and [...] these systems [would] be virtually free of bugs" (ibid., p.863). However, when Dijkstra, thirty years later, spoke again of the progress of computing science, his tone was far less optimistic, complaining that (Dijkstra, 2001, p.92):

> *"The average customer of the computing industry has been served so poorly that he expects his system to crash all the time, and we witness a massive worldwide distribution of bug-ridden software for which we should be deeply ashamed."*

Although Dijkstra's 1972 vision was not realized, over its half-century history, SE has evolved significantly. While the processes and lifecycles identified through SE have yielded improvements in the quality of software being produced, they did not become a "silver bullet" (Brooks, 1987). As explained by the Agile Alliance (Agile Alliance, N.D.), in the late 1990s, a number of different software development methodologies began gaining increasing public attention. Contrasting with the "heavyweight," plan-driven processes associated with much of SE, these were newer, and more lightweight and agile, and eventually became known as Agile approaches. The philosophy behind these approaches is expressed in the Agile Manifesto (Beck et al., 2001) as:

- *Individuals and interactions over processes and tools*
- *Working software over comprehensive documentation*
- *Customer collaboration over contract negotiation*
- *Responding to change over following a plan*

Sommerville (2010) describes the heavyweight processes as involving activities that are planned in advance, with progress measured against the plan. Planning in agile processes, in contrast, is incremental, with change in response to changing customer requirements also easier. While many prominent SE practitioners have suggested that SE development is, in fact, on a spectrum between the two (Boehme & Turner, 2003), it is perhaps Agile's recognition of the need to be able to (easily) change, in response to change, that has had the most significant impact on SE (Rigby, Sutherland, & Takeuchi, 2016).

Paralleling the development of SE itself, SE education has also been changing, with more agile and innovative elements featuring both in content and delivery style (Foster et al., 2018; Towey et al., 2016). Towey (2015), for example, draws on "dirty tricks" (Dawson, 2000) to help give students more realistic software development experiences, an approach that resonates with many of the motivations behind TVET training (Towey, Ng, & Wang, 2016).

2.1.3 ETHE Sustainability

An investigation by Shift Learning (facilitated by The Guardian in partnership with Universities UK) used a series of interviews (together with questionnaires) with UK university vice-chancellors and prominent university members to investigate how UK HE can adapt to the current uncertain UK environment. Current challenges in the UK have arisen because of the volatile political climate and the damage to the reputation of the UK HE sector caused by excessive negative media coverage. These factors have resulted in the reduction of overseas PhD students attending UK universities at a time when universities in Canada and Australasia have reported an increase. Furthermore, amid disputes regarding salaries and difficulties arising because of policy changes, universities have had no growth in undergraduate student numbers in a growing market (The Guardian, 2018). After the privatisation of the UK HE sector, the challenges currently facing UK universities are representative of challenges that may be faced by any privately funded HE institution. Thus, it is essential to deliberate on the issue of ETHE's current and future sustainability to proactively prepare for upcoming challenges.

The issue of funding is most pertinent for the UK universities whose primary focus is not on research, because tuition fees can comprise up to 80% of their income (ibid.). Parallels can be drawn with universities in China and Hong Kong whose funding models depend on tuition fees and government subsidy (Jacob et al. 2018); fortunately, the immediate sustainability of HEIs in these countries is not under threat due to government policies that aim to develop knowledge-based economies. In mainland China, government expenditure (as a percentage of GDP) increased from 2.35% to 4.26% between 1995 and 2015, and in 2015, 40% of the eligible-age cohort were enrolled in HE, the largest enrolment numbers in the world (CMOE, 2016). In Hong Kong, the HE sector has been rapidly expanding with the number of institutions doubling from 11 to 22 between 2005 and 2015 (CSPE, 2019); however, government expenditure as a percentage of GDP declined slightly from 4.45% to 3.41% over the same period. In this case, autonomous funding has been generated from donations, provision of self-financed programs, and by engaging in entrepreneurial and income-generating activities (Jacob et al. 2018).

Although it may seem that in these conditions there is no threat to the future sustainability of HE; however, this is not the case. In Taiwan, although the enrolment rate for 18-21 year-olds has maintained a steady state and international enrolment has increased by a multiple of 3.5 from 2007 to 2015, the enrolment of the non-18-21 population has declined from 2012 to 2015 (TMOE, 2015). Of particular concern is that six out of 164 Taiwanese HEIs closed between 2009 and 2015, while government expenditure on education fluctuated around 4% of GDP. A similar situation may soon occur in the UK, where three universities have revealed potential bankruptcy (The i, 2019). In the case of Taiwan, it is not the political climate that has caused this situation, it is the decline of the birthrate and the change in demographics: The Taiwanese birthrate in 1991 was 15.7%, but fell to 8.99% in 2014 (TMOE, 2014). This ought to be of grave concern to mainland China whose previous one-child policy is likely to create a similar demographic shift and also to Hong Kong whose birth rates have been lower than the required replacement rate of 2.1 children per couple for

the last 38 years (CSD, 2018). Overall, the future sustainability of ETHE looks set to face further challenges.

2.2 Technical and Vocational Education and Training (TVET)

Technical and vocational education and training (TVET) comprises "education, training and skills development relating to a wide range of occupational fields, production, services and livelihoods" (UNESCO, 2015, p.2), and is considered an alternative education route to nurture skilled technicians to suit a country's manpower needs. TVET prevailed in many developing countries in the 1960s, especially in Asian countries and regions such as Japan, Singapore, Korea, Taiwan and Hong Kong. TVET was once a well-accepted pre-vocational and in-service choice for many people as an alternative to studies in universities. Towards the 1990s, most of the aforementioned countries gradually transitioned into knowledge-based economies and there was an increasing need for highly-educated workforces, instead of just the basic manufacturing skill levels. Increasing recognition from professional bodies was another factor attracting youth to university studies.

TVET was a promising study choice in Hong Kong in the 1960s. With factories producing a range of original equipment manufacturing (OEM) products such as clothing, electronics, toys and other goods, Hong Kong was once considered the manufacturing centre of the world (Buckley, 1997), and at that time, technical schools were established to accommodate the need for manpower to supply the manufacturing industries. As Hong Kong began changing to a knowledge–based economy, and manufacturing industries migrated to mainland China in the 1990s (Economist, 2015), Hong Kong's TVET became less popular among young people, who viewed university education as the key to success (Lim, 2014). This resulted in a decreasing number of skilled professional and technical workers in the manufacturing industries. To accommodate industrial demands, TVET had to revamp their programmes and curricula by adding theories, advanced subject knowledge, and a range of transferrable and people skills for potential students to articulate to further studies in universities. In the last decade, many governments and TVET providers have begun to make significant efforts to enhance their curricula and learning and teaching strategies (Ng, 2016). The reformation result is significant, with a trend of people returning to TVET. Thomson (2011) has observed that more students are now studying TVET at both an earlier age, and later in life. In the UK, the total number of vocational qualifications awarded increased by 11% in 2009, driven largely by students undertaking vocational courses at schools (BBC News, 2009). The number of school students aged 15 to 19 participating in Australian TVET also increased by nearly 30%, from 167,100 in 2006 to 216,700 in 2009 (NCVER, 2010). Singapore has also recently set up the SkillsFuture Singapore initiative to "promote a culture and holistic system of lifelong learning through the pursuit of skills mastery, and strengthen the ecosystem of quality education and training in Singapore" (Singapore Government, 2018). To catch up with the global changes, TVET in Hong Kong has also attracted the government's attention.

2.2.1 TVET Sustainability and Feasibility

Recent technological advances, the influence of "Industry 4.0", and a range of economical and demographical factors, have meant that TVET sustainability remains an issue to be addressed (Pavlova, 2016). Diep & Hartman (2016) asserted the need for reformation of TVET in Asia, citing the rapid societal changes. The recommended enhancement would build capability for both TVET teachers and learners specifically in areas related to learning and teaching pedagogies and ecologically sustainable development. Traditional TVET jobs are being replacing by emerging job roles, with new skills and new competencies. The new workforces in the 21st Century require a new set of competencies that emphasise professional trade skills as well as soft skills, including digital literacy, critical and design thinking, and problem-solving, creativity and collaboration skills. Further TVET development will involve close partnerships between industry practitioners and TVET institutions, and the tripartite collaboration between government units, industries and institutions. As pointed out in OECD's (2010) report for sustainable TVET development, "the effective partnership between government, employers and unions [is needed] to ensure that the world of learning is connected at all levels with the world of work". Academically, to sustain life-long learning and successful careers, TVET institutions are reforming their curricula to address the needs.

The 2014 policy address by the Hong Kong chief executive emphasised that "mainstream education is not a straightjacket that fits all young people as everyone has his or her own interests and abilities. The Government should re-establish the positioning of vocational education in our education system and guide the younger generation in choosing their career" (HKSAR Government, 2014, p.102). The Hong Kong taskforce on promotion of vocational education was formed in 2014 to conduct studies and advise on strategies, including rebranding, to better equip TVET learners with "practical skills, attitude and knowledge for the relevant professions and specific industries" (HKSAR EdB, 2015, pp.86-87). Currently, Hong Kong's TVET has a very clear position and articulation paths that stress trade-specific skills to nurture work-ready students as well as preparing them for further studies. The "Earn and Learn" scheme, for example, involves on-the-job training "integrating structured apprenticeship training programmes with clear career progression pathways," and aims to attract and retain young people (HKSAR Government, 2014, p.106). Scheme participants are provided with an allowance and a guaranteed salary, such that they can earn a steady income while equipping themselves with knowledge and skills to pursue a promising career (Ng, 2016). The participants attend training programmes in TVET institutions and receive on-the-job training at related companies. During their study in the scheme, students learn theoretical knowledge and practice in simulated work environments in school; while the learning and practices of "authentic" trade-specific and generic competences such as communication, team-work, problem solving, transferability and work ethics happen in their work engagements in real-life workplaces (Deissinger, 1997; Van Merriënboer, 2001; Tremblay & Le Bot, 2003). In addition, with an aim to nurture potential students to meet the manpower demand in Hong Kong, the Study Subsidy Scheme for Designated Professional Sectors was implemented on a pilot basis to subsidise about 1,000 students in 2015/16 academic

year to pursue designated full-time accredited self-financing undergraduate programmes in six selected disciplines (architecture and engineering; creative industry; health care; logistics; testing and certification; and tourism and hospitality).

Articulation pathways for further studies for higher academic qualifications and career development have also been developed for the students. With TVET pedagogies such as workplace learning, technology enhanced learning, project learning and experiential learning to facilitate learning and teaching (Ng et al., 2016; 2017), Hong Kong's TVET has repositioned itself, and is now more welcomed by students with interests and attributes in professional subjects (e.g. design, culinary arts, applied science).

2.3 The Chinese Context

The Chinese economy over the past thirty to forty years has seen incredible changes. This includes the massive growth through a manufacturing industry boom and the more recent embracing of a service economy that includes technology adoption (such as mobile payments) that many would describe as world-leading (Matsangon, 2018). The more recent turbulence caused by the US-China trade war, however, appears to be starting to have a negative impact (Shane, 2018).

As previously discussed (Li et al., 2012; Towey, 2014; 2016), China has witnessed not only enormous economic changes, but also significant expansion of HE provision. This expansion has included the creation of Sino-foreign higher education institutions (SFHEIs), the first of which opened in 2004, and is the current workplace for two of the authors: University of Nottingham Ningbo China (UNNC).

The authors of this paper have had extensive exposure to HE and/or TVET in China, both in the mainland and in Hong Kong SAR. Prior to working at UNNC, Author-A had previously worked at a different SFHEI, a liberal arts college established as a collaboration between Hong Kong and mainland China: BNU-HKBU: United International College (Huang & Towey, 2010). Author-B was the founding member of CE at UNNC, where he has been for over ten years. He was involved in the successful 2015 ICE accreditation, which made the CE degree course the first in mainland China to be accredited by the ICE, the Institute of Structural Engineers, the Chartered Institution of Highways and Transportation, and the Institute of Highway Engineers. Author-C has 22 years THE and TVET teaching experience, and 16 years management experience. He has been involved in curriculum and programme planning, development, and quality assurance for both local and non-local qualifications, and also has extensive experience in staff development and training.

3 ETHE and TVET Parallels and Challenges

In spite of their very different origins, history, and original motivations, ETHE and TVET currently share many similarities and parallels, including some common challenges.

3.1 Goal: Equip Students with Appropriate Skills

TVET was developed with a clear mandate to serve the local community, providing and supporting very specific and relevant skill sets. This contrasts with the liberal arts approach of aiming to provide a broad and general education (Huang & Towey, 2010) — an aim that has been increasingly pursued by many newer HEIs in China and elsewhere (Towey, 2014; 2016). Indeed, given the changes to expected career paths, and the disappearance of the concept of remaining at one company for an entire career, the definition of what skills are necessary and appropriate in a graduate has also been evolving. ETHE, in many ways, may have begun with more traditional academic intention, but now most, if not all, engineering-related curricula are professional body certified and accredited. This very clear input from the target professional community represents an overlap with TVET.

3.2 Student Similarities

Anecdotally at least, it would seem that perceptions of which students choose ETHE and which students choose TVET retain the earlier biases surrounding both modes: the high achievers aim for ETHE, and those who do not directly get into ETHE consider TVET. The emergence of more articulations and pathways from TVET into ETHE has blurred this progression route somewhat.

Aside from possible differences in academic performance, however, a more interesting inquiry is into how similar these ETHE or TVET students are. Clearly, for example, a student interested in pursuing computer science at TVET is likely to share commonalities and interests with her counterpart in ETHE. An impression that Author-A has voiced relates especially to mature students: given the perceived practicalities in TVET (including scheduling and modularity), it may well represent a more sensible pathway for practitioners to upgrade their skills than ETHE. Such a practical mindset would clearly appeal to potential employers. Since a key indicator of the success of HEIs (both ETHE and TVET) is graduate employability, this is an important consideration. Through workplace learning, TVET students can receive on-the-job training. While theoretical knowledge is taught in TVET, the learning and practice of authentic, trade-specific and generic competences — such as communication, team-work, problem solving, transferability and work ethics — are core to the workplace learning (Deissinger, 1997; Van Merriënboer, 2001; Tremblay & Le Bot, 2003): workplace learning provides “a fertile opportunity for learners to appropriate knowledge that connects theory to practice in a realistic and efficient way” (Billett, 1996 in Smith, 2003, p.53).

Another impression of the contrast between modern ETHE students and those coming through ETHE twenty or thirty years ago, is that students on entry are now often far less certain about their choice of degree program, which, as mentioned in Section 3.1, is a natural consequence of the move away from life-long employment at a single venue. The typical commitment of three to four years for completion of an ETHE degree may well be not only daunting to a new student (ETHE or TVET), but may actually be inadvisable (Towey, 2016). Alternatives, perhaps in the form of more open and flexible educational offerings, may be more appropriate for potential

students at both TVET and ETHE (Towey, 2014).

Being in a Chinese context means that many of our students share some ethnic and cultural background. Although it may be easy to ascribe some of our experiences and impressions to this background, this is not our intention, and discussion of the so-called "Chinese Learner" (Towey, 2014; Watkins & Biggs, 2002; Wong, 2004) is beyond the scope of the present paper.

3.3 Teachers

There is on-going debate over the role and qualification of the teacher in HE. ETHE, for example, often focuses on academic or research records rather than actual teaching skills. Recent controversy over the treatment of adjunct professors in the US, where some are so poorly remunerated or cared for that they are officially below the poverty line (Saccard, 2014), has highlighted some of the challenges facing HEI teachers. Although these challenges may be most visible in the US context, they are increasingly global.

Controversy aside, however, there is increasing attention paid to enhancing teaching skills in ETHE and elsewhere. Reported student feedback on teaching cites the desirability of practicing or industrially experienced faculty (Xie, Towey, & Jing, 2014) — adjunct faculty, in other words. Unfortunately, academics with significant industrial experience are very scarce, a natural consequence of their academic focus, and thus if ETHE continues with the traditional model of its research staff composing the majority of its teaching staff, the tension will continue. TVET, in contrast, has typically looked to practical or industrial practitioners for its teaching staff (Pan, 2007). Although this is less common in ETHE, it is nonetheless increasing.

3.4 Stigma

Author-A notes that software engineering (and computer science, in general), like other STEM subjects, has often struggled with gender-imbalance, stereotypes, and stigma. The SE community – professionals, students, and academics – is frequently presented as socially inept males. While this was especially true in the past, in the West, our experience in greater China has been more positive. Computer science at UNNC, for example, has a much more even gender balance (Towey et al., 2015). The wealth generated (and possessed) by many of the so-called geeks and nerds of the 1980s also seems to have tempered much of the negativity surrounding their image.

TVET may also have some associated stigma. If perceived as a lesser HE option than ETHE, the stigma could permeate both the student and teacher communities, and persist into the careers of both. The recent enhancements to TVET in Hong Kong (HKSAR, 2014; HKSAR EdB, 2015) and elsewhere suggest that, like the rich geeks of the 1980s, a TVET without (or with less) stigma may be in the near future.

3.5 Teaching and Learning: What and How

Related to the earlier discussion of parallels between TVET and ETHE skill provision (Section 3.1) is the core issue of what the students should learn. Even more significant, especially given the changing landscape of teaching and learning, is the question of how they should learn it. TVET depends heavily on workshop practices and workplace learning rather than lectures, literature reviews, and tutorials (Towey, Ng, & Wang, 2016). This mode of delivery may be more appropriate for both the skills involved, and the learning preferences of the TVET students (Ng, 2016), but may also lack the scalability or sustainability that lecture-based delivery has. In contrast, while lectures have been identified as a very efficient mode of information delivery, their actual positive impact in learning has been challenged (King, 1993; McWilliam, 2009).

These questions of content and method of delivery are not unique to either ETHE or TVET, but do remain important challenges to both. The increasing availability of alternatives to traditional delivery, and to both TVET and ETHE themselves, is also raising again the need for TVET and ETHE to adapt and evolve. Alternatives such as open and flexible learning resources may indeed represent an attractive and viable alternative to TVET and ETHE (Towey, 2014).

3.6 Funding

A core tension at the heart of many HEIs is that of funding. How are the buildings, classes, teachers, materials, and so on, all paid for? Where government funding or subsidy is available, are there attached conditions? How sustainable are HEIs that rely on such intervention?

A common funding model, and one quite prevalent in the various SFHEIs that have appeared recently, is that the majority of funding may come from student tuition. Where the SFHEI also has a research portfolio, this may also form part of the expected income and funding (as is the case in UNNC, for example).

The funding problem, of course, is two-fold: where is the necessary funding coming from, and what implications may some funding sources have for the operations of the HEI. SFHEIs, with their much shorter history, and their frequent need to adapt and overcome obstacles (Towey, 2016), may have an already adopted agility in managing this issue from which other ETHE and TVET institutions may learn.

3.7 Attracting Students

If student tuition fees are an important part of the funding model for an HEI, then clearly attracting students is an essential activity. Even apart from funding, though, the recruitment of students is an increasingly competitive process (as diecussed in Section 2.1.3). The expanded provision of HE combined with the now plateauing of potential student numbers has meant increasing emphasis on getting the students.

Whatever the motivation for trying to attract students, it remains a challenge for

both TVET and ETHE. In spite of the reported attitude of some academics (who may claim that the HEI's most important role is research, not teaching), it seems that student opinion of an HEI (and of both ETHE and TVET) may continue to be an important influence on the HEI's potential continuation and survival.

3.8 Outcomes and Ambiguity

The recent series of disruptions to traditional industries, including accommodation through AirBnB and taxis through Uber, has not bypassed education. Disruption has come in many forms, including an accountability for teaching that has long been overdue. The cost of HE for students has risen so substantially, worldwide, that their natural reaction of demanding more for their investment is not surprising. Recent attempts to centre the educational experience around the student are welcome, but given the increasing provision of alternatives, such as flexible and more open education, HE may face more serious disruption.

A traditional goal or intended outcome of ETHE is to attain a qualification, typically a degree, and thus become qualified for a career path. TVET, too, was focused around skill development and provision, and eventually, through potential articulation with HE, a path to a degree. The problem with all this, and something that is seldom openly discussed, is the issue of qualification compared with actual skill sets: as industry (especially IT) has been complaining, they are not synonymous. Some of the most highly qualified graduates are not immediately ready for the workplace; and some of the most skilled programmers have few, if any, formal qualifications. The opportunity to develop skills outside of ETHE and TVET, and to do so at relatively little financial cost, has become a major threat to both. One cited possible future for HEIs in the face of such threats is as a potential gatekeeper, in an examination or certification role.

These changing outcomes and roles represent an ambiguity of purpose for ETHE and TVET, and are disrupting the related institutions. Some institutional responses include attempts to address everything, presenting themselves as one-stop solutions to all challenges. Unfortunately, such a response has little chance of actual success, and may simply serve to reinforce the disrupted state of the institution.

3.9 Impact of Education 4.0

Paralleling the developments in "Industry 4.0" (Pavlova, 2016), the education sector is also predicted to see further impact from digital transformations. Although, ironically, ETHE might not yet have been perceived to have benefitted as much as other disciplines (Towey et al., 2016), this is set to change. The increasing use of big data analytics to support personalised learning journeys, and the promise of artificial intelligence-led teaching and learning developments mean that ETHE (and VPET) disruption is much more a question of when than if. Resistance to these changes and the uncertainties surrounding them are unlikely to be successful.

4 Conclusion: Agility for Sustainability

As was acknowledged in the field of software engineering in the late 1990s, uncertainty is not something that can be ignored. Indeed, the modern, agile approaches have embraced it, leading to customer or stakeholder-oriented interactions and emphasis that were previously unheard of. The SE Agile movement has seen a lot of success, and while also not a universal silver bullet (Brooks, 1987), may have some principles that could be applied to ETHE and TVET to help address and overcome current and future challenges. Most urgently, an identification of the major stakeholders in both ETHE and TVET is a prerequisite to any attempt at better communication and interaction. These stakeholders must include the students, and must emphasise their input. The ambiguity surrounding many ETHE and TVET organisations should not be seen as a purely negative force, but rather, as has been seen in CS, an opportunity to call the stakeholders together and develop a better communication and provision.

An embrace of ambiguity and agility will also impact future related research directions. The promise of Education 4.0, and the further disruptions of education through the affordances of evolving education technology, will open up new opportunities for education research. We anticipate that the concept of agility will support new and exciting innovations in the literature of HE sustainability.

5 Future Work

Our future work will include exploring how agility has been harnessed in engineering disciplines beyond civil and software, and what differences the expectation and acceptance of ambiguity may have had in the successful implementation of these engineering disciplines. We will also examine the research potential of agility as a guiding principle in HE. Since the context of this paper has been greater China, we also look forward to investigating in more detail the experiences and perceptions of others practitioners outside of our context, exploring how similar their situations and perspectives may be. At a personal level, we will also continue to apply agility in our own professional practices, attempting to approach and address challenges from an agile perspective.

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