Looking beyond the West for emerging leaders in engineering education reform: A case study of two Chinese engineering schools informed by neo-institutional theory

Abstract— **This work-in-progress paper considers the current state of curriculum reform in engineering education in China (presently the world's largest producer of engineering graduates), with an empirical focus on innovative curricula at two prominent schools. Tsinghua University is a well-established leading institution of engineering education in China, and likely the best known internationally due in part to its inclusion in the MIT report The Global State of the Art in Engineering Education. The Southern University of Science and Technology (SUSTech) is a new university established just over ten years ago, which is nonetheless already prominent on the national stage for its innovative engineering programs. Our study compares the Tsien Class at Tsinghua University with the SDIM curriculum at SUSTech and finds that while they are both drawing on global ideas to design these innovative curricula designed from scratch, that the local contexts also influence the forms of curriculum adopted. The Tsien Class is very much focused on academic research, and has individual students designing projects and building global links. SDIM is focused on industry collaboration and uses a project-based learning design which has students working in groups on relevant interdisciplinary projects.**

Keywords—curriculum reform, neo-institutional theory, leaders of engineering education

I. Introduction

In 2018, MIT released its report entitled "Global State of the Art in Engineering Education" [1]. Drawing on interviews with a wide range of "thought leaders" and in-depth case studies, it identified engineering schools deemed to be the ten "current leaders" and the ten "emerging leaders". The former group, all US or European institutions except for National University of Singapore (NUS), have curricula that feature user-centered design, technology-driven entrepreneurship, active project-based learning, and "rigor" in engineering fundamentals. The group identified as "emerging leaders" are again predominantly from the US or Europe, but with the inclusion of two universities from Singapore (notably NUS was also featured as an "emerging leader"), together with one university from Chile, and one from China (Tsinghua University). The MIT project was designed to obtain opinions on institutional reputation rather than other measures, and the findings also depended on the global location of the interviewees, as was acknowledged. Using this approach, the findings of the report reflect the contemporary Western dominance in setting the standards for engineering education. At the same time, the MIT report also anticipates a "tilting of the global axis of engineering education leadership" (p. iii) but is not able to give substantive empirical evidence to this effect.

This study aims to narrow this gap in research by documenting emerging leaders in engineering education beyond the Western context. Specifically, we are focused on China where the context for engineering education reform is fast-moving. In 2017, responding to the growth of engineering enrollments and the dramatic engineering education reforms, the Chinese Ministry of Education proposed a three-stage sequential policy, the Emerging Engineering Education (3E) initiative [2]. The 3E initiative encouraged universities to establish new engineering programs or revise existing ones and to explore talent development mechanisms. This study builds on our previous work where we analyzed these policy documents [2] and showed how Chinese engineering education policy is following the current global trend. We had also conducted an exploratory study of the problem-based curriculum at one of the institutions under focus which started to suggest that the innovation, while globally inspired, also featured some pedagogical practices already well established in Chinese culture.

For the current study, we chose to compare two "experimental" programs of engineering education that we found at two leading institutions which have very different histories. One of these programs is considered the "top's top": Situated in China's most prestigious and influential university, the Tsien Class is the signature program of engineering education innovation at Tsinghua University, designed to explore new paradigms to cultivate top talents. The other program, the SDIM (School of System Design and Intelligent Manufacturing) in SUSTech might be considered the "edge of the edgy" engineering education. SUSTech is an influential innovative university that aims to push the boundary of China's higher education reform, and SDIM, a brand-new school, is the university's latest attempt at engineering education reform.

Both of the case study programs claim to depart from traditional engineering education. In some ways they are quite similar in their endorsement of active learning environment, undergraduate research, and in their pursuits of innovative ways of teaching and assessing engineering talents. Our study aimed to look more closely at these curricula to determine the features of each approach and where there were similarities and differences.

II. Research Design

This study uses case study methods to analyze the two contexts in China [3]. Our data came from the websites for both programs and related literature. In the author team we have researchers who have worked or presently work at each institution, and so we also had broader contextual knowledge that we could use in interpreting the documents.

Our analysis methodology for this exploratory work-in-progress study is a basic content analysis where we systematically identified key features of each program [4]. In interpreting our findings, we drew on neo-institutional theory to attempt to construction explanations for the observed similarities and differences.

Using case study does not deliver findings that are generalizable in the traditional sense [5]. But case study allows readers to determine the applicability to other contexts [6].To ensure research quality, measures of transferability should be incorporated into the study as described by Lincoln and Guba [7].

III. theoretical framework

We have a longstanding interest in comparative perspectives on engineering education reform globally. An earlier study by one of us compared three institutions across the African continent and showed that while all were informed by global perspectives, each had very strong local contextual influences [8]. To guide this study theoretically we drew firstly on Pierre Bourdieu's field theory, conceptualizing the university as a semi-autonomous space in society [9]. The level of this autonomy is captured by Bourdieu's concept of refraction, which expresses the degree to which a university entity is able to mediate (or refract) outside influences. In being able to consider in more detail how curriculum gets formed, we drew on the work of another sociologist, Basil Bernstein, who conceptualizes the process of contestation whereby disciplinary knowledge is recontextualized (his term) into curriculum [10].

For this study we retain these broad influences, but here we have also recruited neo-institutional theory, as used in a recent study by Klassen and Sa on the influence of global systems of accreditation on the academic organization of engineering programs in Canada [11]. Neo-institutional theorists point to the increasing rationalization of organizations such as universities, where ideas from dominant countries become widely adopted as local actors seek to conform to societal expectations. Three main "pillars" of institutional order offer insights into how and why this conformity occurs: 1. the regulative pillar (explicit laws such as the Washington Accord in global engineering accreditation); 2. the normative pillar (a moral motivation related to social obligation); and 3. the cultural-cognitive pillar (shared ideas). In the context of global engineering education reform, much literature focuses on the regulative requirements of the Washington Accord. Normative pressures, however, can be considered to be more localized, as with cultural-cognitive influences, although with the global emergence of Engineering Education Research (EER) these have a considerable reach presently. In their study, Klassen & Sá show that while global convergence can be anticipated in curriculum reform as per the phenomenon of isomorphism, which is shown relative to these norms, when analyzing at the local level they find substantial variation in the institutional patterns that are followed.

IV. Case study institutions

The education objectives of both programs align with the strategic positions of their hosting universities. Tsinghua University is a top university in China that explicitly commits itself to "education and research at the highest levels of excellence". Established in 1911, the university currently focuses on "developing innovative solutions to solve pressing problems in China and the world" [12]. As an example of top-level talent cultivation pilot program at Tsinghua, Qian Xuesen Excellence in Education Program of Tsinghua University (hereafter called "Tsien Class") was founded in 2009, to adhere to "Qian Xuesen's Question"—Why did universities in China fail to cultivate top innovation talents? —a question raised by the canonical rocket scientist Qian Xuesen. The Tsien Class is positioned as the preeminent engineering endeavor in the national "Experimental Program for Training Top-notch Students in Basic Disciplines" [13].

The faculty of Tsien Class operates by a chair professor responsibility system, and has a high-level International Mobility. Tsien Class hires well-known experts and professors in different research fields nationally and abroad, including Nobel Prize winners, to set up an advisory committee for each student. The education objective of Tsien Class is to cultivate innovative and excellent engineering talents based on basic engineering research.

SUSTech was established in 2012 and emerged from strategic proposals by the municipal government of Shenzhen, the sixth largest city in China, and one of the most vibrant economic powerhouses, following its designation as the nation's first special economic zone in the early 1980s. Politicians and educators in Shenzhen had long felt that the city lacked the level of higher education suitable to its economic profile. Located in "China's Silicon Valley," founders of SUSTech were inspired by the idea of building a CalTech or a Stanford in Shenzhen [14], [15]. This orientation is reflected in the school's motto "topping the sky and standing on the ground(顶 天 立 地)" "Dingtian"(topping the sky) means aiming at a the frontier of global science and technology development, whereas "Lidi"(standing on the ground) indicates staying rooted in Shenzhen's regional economic strength [16]. Responding to this orientation, SUSTech established SDIM in 2018, as a platform for engaging in radical reform of engineering education and with a mission to cultivate future innovative and entrepreneurial leaders [17].

SDIM aims to cultivate great T-shaped engineers with solid professional foundation, based on training on engineering management, design and practice [18]. Like Olin College in the USA, SDIM hires global engineering faculty from engineering academic and industry fields who have great passion and ideal for engineering education reform. SDIM faculty have a firm and strong innovation drive to lead new engineering education reform.

V. Curriculum comparison

Aiming towards "future masters in engineering", the Tsien Class was set up as a pilot program to guide systematic and progressive cultivation of knowledge and research skills required for solving contemporary urgent challenges. While SDIM curriculum is designed from scratch and based on what it terms "the new engineering education model," it tends to focus more on the applied and practical aspects of engineering competency.

A. The Tsien Class

The Tsien Class breaks away from the conventional curriculum structure at Tsinghua with its advocacy for active and exploratory modes of learning – "learning by doing" is a motto that has inspired this program. The whole curriculum system has required the comprehensive transformation of the core course modules. Learning of professional courses has changed from a unidirectional transmission lecture-based mode to a curriculum centered on challenge-based education and active learning. Humanities and literacy module is included to equip students with comprehensive knowledge in culture and arts and in patriotic ideologies, to cultivate broader interests; By creating a brand-new innovation and scientific research practice module, self-guided, individual research and innovation practice itself become the core learning method. This course module aims to fully inspire students to devote themselves to the practice of exploration and research.

In the sections to follow we give more details on key aspects of the program.

1) Self-guided and progressive system of undergraduate research

The choice of mechanics as the foundational discipline yet not as a "major" in its traditional sense opened a new space for training in "innovation and research practice" [19]. The progressive research for learning system (PRLS), comprising four modules, is a gradual process spanning from freshman to senior years. This system stimulates students' intrinsic motivation for self-guided learning and practice, guides students to find scientific research interests, and inspires their innovative research potential [20]. PRLS consists of four systematic research and practice modules, totaling 16 credits for research courses among the 138 credits required for students in the Tsien Class.

2) Basic training for broad openness

ESRT (Enhanced Student Research Training) encourages students to actively explore research interests. ESRT (3 credits) offers a fundamental training of research for freshmen and sophomores, which has no major limits, and which helps students to explore and develop their research interests as soon as possible.

3) Immersion in academic conversations

X-idea (2 credits) is a seminar-based course with invited speakers, provided for freshmen and sophomores, focusing on a series of major issues in academic frontiers, national strategies, and front-end industries. X-idea invites outstanding experts, scholars, tech leaders, and celebrities with experience in various fields to give talks and interact with students.

4) Autonomy in research operation

ORIC (Open Research for Innovation Challenge) provides research guidance and support to match students' individual research needs. Students can have enough opportunities to explore and develop individual and innovation projects to do responding academic studies. ORIC, with 8 credits, offers junior and senior students opportunities to explore innovative projects independently, in addition to a 10,000 RMB research fund for each student.

5) Freedom to cooperate with global researchers

SURF (3 credits) provides students three to six months overseas research experience. Students have the freedom to reach out to global partners to attempt to find placements for this research experience. SURF helps students to find the most suitable guidance of experts, and conduct research in global laboratories [21].

B. SDIM "1+3" curriculum

SDIM features an overall "1+3" structure, where students receive general education and basic subject education in the first-year, taught with traditional teaching methods, laying a solid and broad foundation for professional learning. From the second year, the curriculum shifts into a focus on professional learning, using project-based learning methods to cultivate students' engineering knowledge and professional abilities. Students majoring in Industrial Engineering have six different choices of individual major directions: design, intelligent manufacturing engineering, mechanical engineering, materials science and engineering, computer science and technology, and electrical and electronic engineering.

We provide below a brief overview of some of the key features of this curriculum from the second year onwards:

1) SDIM Project-based Courses

The curriculum includes both project-based courses and stand-alone projects. During the project-based courses, instructors deliver some lectures to introduce relevant engineering theory and basic knowledge. They then require students to finish what are termed "bitesize" projects as a way to acquire related knowledge. The final assessment at the end of the semester is not a set of exams but an Integrated Project, which involves all the main courses in every semester. For example, the sophomore Integrated Project "Designing a robot" involves five project-based courses: Design Thinking and Engineering, Electronic engineering and Analog Circuits, Material Engineering, Rapid Prototyping, 3D printing, and Mechanical Engineering. Each course uses its syllabus to design various bitesize projects which all help students prepare for the integrated project.

2) Stand-alone projects

Since each SDIM student has six choices of individual major directions, every project team is comprised of leaders from each of these majors. For example, in the integrated project to design a robot, the main task of the group members in terms of electronics is to connect the infrared receiving circuit, so the group members need to systematically master the theoretical knowledge of SDM242, “Analog Circuit System Design.” Each group will elect an electronic guide, who will figure out electronic issues about the project ahead of others, and then lead on the dividing up of electronic tasks.

3) Industrial practical programs (Experiential Learning)

Students at SDIM engage in industrial practical programs every month. For example, professors in SDIM took advantage of the 8th Shenzhen International Industrial Design Exhibition to offer students an industrial practical class which provided students with close contact with the industrial design community and engineering business community.

4) SDIM Innovation Research Lab

At SDIM, undergraduates can apply to join different laboratories according to their professional interests, and substantially participate in the teachers’ scientific research projects. When students decide their major directions, through the mutual choice of undergraduates and faculty, students contact supervisors whose research areas match their interests. SDIM has twelve academic supervisors who are the leaders of five innovation research labs. During the cooperation in innovation research labs with their advisors, students can independently conduct experiments, learn how to write literature reviews, and practice other research tasks. Undergraduate research is not mandatory, but students are highly encouraged to find their research interests early and master some necessary academic skills for a research study.

VI. Discussion & Conclusion

China is presently undergoing substantial curriculum reform in engineering education, but this is not much known globally. The recent MIT report entitled “Global State of the Art in Engineering Education” [1] acknowledges this, and suggests that future leadership will come from emerging economies. Our work-in-progress study of two prominent engineering schools in China who are seeking to lead with their innovative curricula aims to contribute to this gap in the literature.

What our study showed in its analysis of these reforms is that both programs are definitely influenced by the overall national ambition to be world-class universities and disciplines, and thus to be looking globally for innovative ideas. They move substantially away from the highly theoretical and examination-driven modes of curriculum that had been common in Chinese engineering education, and embrace active learning pedagogies, student-driven projects, open-ended relevant problems and a focus on developing professional skills holistically.

We noted significant differences between these two curricula which seem related to the different institutional histories and missions. Tsinghua has a program which is very much focused on research – this makes sense given this institutional context of a top research-focused university that has been prominent nationally and globally for decades. In the Tsien Class, students work individually, conceptualize their own projects, and have close connections with the faculty. SUSTech, on the other hand, has started the SDIM program that seems very much influenced by industry needs, and is a core part of this university’s mission to be strongly connected to the economic development in Shenzhen. SDIM has thus adopted a PjBL curriculum that has students working in groups on industry inspired problems.

Overall, the study shows the richness of the potential for curriculum reform in engineering education globally, and the value of looking comparatively at potential “emerging engineering leaders” in engineering education. In the light of neo-institutional theory, we note global influences, but our analysis which scratches beneath the surface of terminology shows how both institutions were able to act with considerable autonomy. Both of these curricula were able to be developed from a “blank slate” and the institutions put forward the resources and commitment to do these engineering education reforms. This is potentially an advantage of the publicly funded system of higher education in China which is less dependent on tuition income and more focused on following the policy objectives of the government, which in this case are strongly focused towards innovative curricula and the goal of world-class status for engineering schools.

We also note that compared with the widespread adoption of ABET norms through the Washington Accord globally, that while some Chinese institutions have linked up to the accord, in general curriculum reform in China is not driven by ABET norms but rather by government direction. Contrary to what many westerners might assume, this actually allows for quite significant innovation at the elite schools. Our study shows how these engineering education reformers have drawn on the global discourse in relation to the necessary reform of engineering education, but they have recontextualized it for the local context, as shown in two schools who have implemented quite different innovative curricula.

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