2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39598

# Innovating Engineering Curriculum Design Toward Future: A Pilot Case Study of the School of Future Technology (SFT) in China

**Dr. Lina Zheng, Beihang University**

Lina ZHENG is a postdoc researcher at Beihang University, and holds a Ph.D. degree in Public Administration from Tsinghua University. She used to be a visiting scholar in the School of Engineering Education at Purdue University, with long-lasting interests in global engineering education research and practice.

**Yu Han**
**Ruilin WU**
**Jianglong Zhang**
**Ye Jinxin**
**Zijiao Jiang**

# Innovating Engineering Curriculum Design Towards Future:

## A Pilot Case Study of the School of Future Technology (SFT) in China


## Abstract

The burgeoning advancement of technologies has been calling higher educational system to actively respond to the rapid changes in recent years. Regarding engineering education, how to prepare students for continuously emerging technologies and global challenges towards future remains largely unexplored. Accordingly, China launched the *New Engineering Education* (NEE) initiative since 2017 to transform Chinese engineering education in terms of re-structuring programs and re-designing curricula to be more interdisciplinary and future-oriented. Following closely, the Ministry of Education of the People's Republic of China (MOE) has been further refining the layout of NEE via established a batch of School of Future Technology (SFT) within 12 research-intensive universities. Since the construction of SFTs is now in the second year of student enrollment, the setting for this study is aligning with the development of SFT, therefore, we adopt a pilot case study approach in context of Beihang University (BUAA), to identify recent approaches best practices in re-designing engineering education curricula towards future. In this paper we present the design of "STEP by STEP" curricular structure with course threads (the first "STEP") and project threads (the second "STEP") jointly preparing students with the remixing competence towards the ever-changing technology trends (the helix effect identified via "by"). This curricular structure brings university and the industry closer and engage students in as both learners and contributors via the progressive projects and mentor groups.



**Key words**: School of Future Technology (SFT); curriculum design; remixing


## 1. Introduction

Efforts to innovate the approaches we educate future engineers are by no means new, but the increasing interests in introducing the emerging technology trends into informing engineering education activities are constantly new-found. Accordingly, the curricula of engineering education are continuously called for re-design around the globe, to actively respond to the rapid changes under the context of the New Industrial Revolution. In this paper, we attempt to investigate activities of the *School of Future Technology* (SFT) in China, which is launched in 2021 and considered as upgraded initiative of the overall layout of *New Engineering Education* (NEE). The initiative of SFT is aiming at prospectively educating future engineers with the foresight to grow aligning with the rapid development of emerging technologies towards future, as well as innovate engineering education paradigm (MOE, 2021). First cohort of SFTs are established at 12 research-intensive universities including Tsinghua University (THU), Peking University (PKU), BUAA, et al., and diverse practices for the construction of SFTs are encouraged.

In particular, we adopt a pilot case study approach in the context of SFT initiative, to find out how the curriculum is designed to prepare students for continuously emerging technologies and global challenges towards future. For convenience of data collection and analysis, we choose the SFT at the authors' home institution - Beihang University (BUAA) - to explore both the underlying laws of re-designing engineering education and the reforming activities.

The setting of this study is the launch of SFTs at 12 top research-intensive universities in China since 2021. To describe the case of SFT, we introduce the "why-what-who" framework to focus on the curricular philosophy, construct, and participators of the curriculum design. To the end, we attempt to answer the following research question: how the curriculum design of SFT tells us about the present state and probable future trajectory of engineering education reform represented by the SFT initiative in China? In our analysis of the case, we report on how the curriculum is designed with questions about the calling for engineering education reform.

In the following sections of this paper, we first introduce recent studies on latest activities to transform engineering education globally, particularly, the NEE initiative in China. In the second part, we describe our method and specification of the case context. After presenting such context, we address our main research question by analyzing the curricular structure of the case under the "why-what-who" framework. We conclude by highlighting the philosophy and main themes of the SFT curriculum and inform future opportunities. By clarifying the "STEP by STEP" curricular structure, this paper intends to share recent activities in the field of engineering education in China. Therefore, the aim of this study includes twofold: (1) to identify recent approaches in re-designing engineering education curricula towards future; (2) and to share best practices that innovating engineering education in China.

## 2. Literature review

### *2.1. Transforming engineering education curricula towards future globally*

For the past decades, both engineering educators and researchers have been working to carry out the visions of engineering towards future, remarkable milestones include clarifying accreditation criteria of engineering programs (ABET,1996), identifying attributes of engineers in 2020 (NAE,2004), as well as conceptualizing and institutionalizing Engineering Education Research (EER) to inform practices (Jesiek et al., 2009). Regarding engineering curricula, previous attempts have been largely concentrated on coursework or project-based efforts (Maciejewski et al., 2016), with increasing interests on capstone design courses/projects since the adoption of EC2000, (McKenzie et al.,2004; Wilbarger & Howe,2006). These efforts aim at preparing engineering students for future needs with real-world problems, to help students gain not only technical skills but also non-technical skills such as communication and teamwork (Hotaling et al., 2012). However, most engineering curricula remain traditionally, focusing on scientific foundations and technological achievements, also increasing emphasis on design (Hadgraft,2017). Approaching a more holistic perspective around globe, institutes such as Olin College of Engineering (Olin), Massachusetts Institute of Technology (MIT), Eindhoven University of Technology (TU/e), and University College London (UCL) are reforming engineering education in terms of program re-structuring, flexible curriculum designing, and pedagogies innovating to reflect challenges facing engineering in modern society.

Olin serves as an unique story of integrated academic experience (Olin,2017). The college proposed that students should be prepared to predict, create, and manage future technologies, rather than simply respond to technologies of today (Somerville et al.,2005). As a result, Olin held a philosophy of educating whole person and structured the curriculum with flexibility, which integrated scientific and engineering science coursework with projects (Kerns et al.,2005), as well as included engineering design experiences and students' personal interests, to educate not only technical skills but also personally important competencies. Academics in China have shown continuous interests in the Olin experiences around project-based learning and interdisciplinary curriculum design (Wu & Zou, 2013; Li,2010). MIT offers another example to resign undergraduate engineering education towards future via the *New Engineering Education Transformation* (NEET) initiative (Crawley et al.,2018). NEET is an interdepartmental certificate program featured by 11 ways of thinking, project-centric curricular construct, and threads consisted of courses and projects, with an aim to better educate makers and discovers who are able to address critical societal challenges in the 21st century. The curriculum of NEET is designed to be systems engineering based and project-centric, which is more naturally aligns with the "new machines and systems" issues embedded in how the industry operates (Crawley et al.,2019). Inspired by the NEET approach, engineering educators and researchers in China also engage in investigating its design and ideas and identify best practices that might provide possible lessons for China's engineering education reform (Xiao & Tan, 2018; Liu et al., 2021). Other cases such as TU/e is innovating the way students learning through research-informed challenge-based learning (CBL) practices (Reymen et al.,2022), UCL develops a student- centered and cross-disciplinary model of curriculum titled Integrated Engineering Program (IEP), which is implemented with problem-based learning experiences to inserts both cross-cutting technologies and threads of activity into existing discipline-specific curricular structure to bring together students' theoretical learning with practical skills and provide them an overall landscape of engineering to collaborate, design, and innovate (Mitchell et al.,2021).

Drawing on these practices and research findings, we can theorize about what is going on engineering education reforms responding to industrial and societal challenges globally. Today's engineering education in engaging students in their own learning process to balance classroom course learning, design projects, and individual development. Accordingly, engineering curriculum is changing from disparate courses reform and update to integrated curriculum design, which is facilitating collaboration across majors, disciplines, and departments in concert with students' technical and nontechnical skills to identify and design innovative solutions to societal problems and challenges.

### *2.2. Recent engineering education initiatives in China*

Significant milestones of engineering education in China over the past two decades include launching the *Plan for Educating and Training Outstanding Engineers* (PETOT) since 2010, becoming signatory member of the Washington Accord in 2016, the NEE initiative which is considered as upgraded version of PETOT in 2017, the SFT initiative and *College of Modern Industry* (CMI) initiative in 2021, and the *National Supervisor College for Engineers* (NSCE) in 2022.

Around these reforms, researchers, educators, and industry partners hold macro policy perspectives (Wei et al.,2022; Lin, 2017), meso-level institutional study views (Lu et al.,2018; Ye et al.,2022), as well micro classroom teaching and learning research (Tian et al.,2021; Fu & Liu,2020). These strategies share a vision to improve the quality of engineering education and transform China's engineering education to be future- and industry-oriented, to provide students with both broad range of knowledge, complex problem-solving skills, and soft skills to work effectively in industry and contribute to technological achievements. Stakeholders enrolled including the government, industry, deans of engineering schools, faculty and students reach in agreement that China's engineering education needs to actively respond to the rapid changing world and societal impacts. For instance, the NEE initiative is implemented through a three-phase design including "Fudan Consensus" "Tianda Action" and "Beijing Guideline", to systematically transform engineering education. Specific approaches adopted vary from upgrading traditional engineering programs such as Mechanical Engineering and Electrical Engineering, restructuring engineering programs to be interdisciplinary, and newly establishing engineering programs towards emerging technologies (Lin,2017). Regarding the curriculum, engineering schools are challenged to review and update their existing discipline-based curricula, not only redesigning the overall curricular structure covered traditional engineering programs and emerging engineering programs (Zeng et al.,2020), but also reflecting and restructuring courses (Li et al.,2022) to educate core competencies (Zhou et al.,2021; Guo,2021); these courses cover both technical and general education ones (Wang et al.,2021; Luo et al.,2020; Cai & Ding,2019). As Crawley (2015) indicated, the undergraduate engineering curriculum is faced with not only diversified and interdisciplinary technical knowledge, but also ever-increasing demands for well-rounded engineering graduates.

Although diverse approaches at different macro-, meso-, and micro-levels have been adopted in innovating engineering curriculum, it is still widely acknowledged that strong foundation in science, mathematics and engineering science is necessary for engineering students, the underpinning scientific and technical knowledge in these foundational disciplines are commonly associated with engineering design and problem solving. At the same time, both skills shortages and skills gaps in engineering graduates are highlighted. Stakeholders including the government, the industry, engineering educators, and researchers have been claiming that engineering curricula should equip students with skills required for addressing current and future challenges (Wu et al.,2017; Lin, 2021). For any research-intensive university to deliver engineering education reforms to students, it is accountable strategy rather than only vision would contribute to substantial changes. Traditionally, innovations and changes can be most commonly identified in strategies such as the introduction of capstone projects in different learning stages to facilitating project-based learning, as a result of which skills such as engineering design and problem-solving might be better prepared (Han et al., 2019). However, growing demands for simultaneously develop engineering education and student as whole person are increasingly unavoidable, the dilemma of more student-centric and large-scale engineering education still exists (Huang et al.,2022). Therefore, top universities are continuously recognizing the impending need to provide students with more opportunities for personalized learning and practical engineering that can help them acquire transferable skills to address societal needs and challenges in the future.

## 3. Method and specification of case context

### *3.1. Research Method*

The curriculum design of SFT is facing with the challenge to breakthrough path dependence on traditional engineering education featured by disciplinary context and solid foundation on science, therefore, the case study method offers an appropriate strategy to examine the context and conditions in-depth (Yin, 2011). Accordingly, we adopt a pilot case study approach to uncover the changing process while designing the overall curriculum of SFT. It is conducted on a single case study supported mainly by fieldwork. The researchers' own on-site observations and participations of the case over one-year time and extensive access to both first-hand and secondary data of SFT. The main fieldwork is carried out on-site in SFT at BUAA, with observation of long-lasting curriculum design meetings, focus groups with stakeholders (i.e., industrial participators, administrators, faculty, students), researchers and individuals from other universities interested in the SFT initiative also provide thoughtful data throughout the study. The field notes from these observations and participations, interview records, and documentary materials are used to cross-checking to triangulate the data collected in this study. Specifically, the data we collected including forum records with the industry (n=3), and focus group records with first-round of students enrolled in SFT (n=2), field notes from lectures given by industrial partners (n=13), panels with faculty (n=6), and informal discussions every so often. Apart from these on-site data, archival data is collected in forms of public policies, newsletters, and relevant national guidelines for SFT. In the subsequent analysis, we follow the four-state analytical framework Morse (1994) proposed in data analysis including comprehending, synthesizing, theorizing, and recontextualizing, complementally, we adopt the ground theory as useful technique supported by the NVivo software.

In this paper, we follow the cognition of curriculum practice by Goodlad (1979) in considering a curriculum as more than just a set of courses but a design of educational system that includes both theoretical and practical elements. Therefore, our case study strives to not only describe the present state about what the SFT curriculum is but also uncover the underlying logics and ideas about why and how such curriculum is designed and implemented to show the probable future trajectory.

### *3.2. Specification of Case Context*

The investigation of this study is based on an in-depth case study of BUAA at school level, as has the utility of relying on a single case study. The effectiveness of case study research has been affirmed by a number of prominent scholars (Eisenhardt, 1989; Yin, 2009), in this study, we specifically choose SFT at BUAA as single case. We seek to explore curriculum design in the existing disciplinary context as part of long-lasing engineering education reform. Case study research well supports our investigation as it "allows the investigation of complex, fuzzy, and dynamic phenomena where context is essential, and there is no limit to the number of variables and links" (Urde et al., 2007). According to the terminology Yin (2009) proposed, our study can be regarded as a pilot single case study which is reported via a narrative approach. We first conceptualize SFT and its institutional context to introduce the background, vision and goals, and organizational structure of SFT.

The SFT at BUAA is one of the 12 SFTs firstly established in 2021 (MOE, 2021). These 12 institutes are all research-intensive universities and World-Class University Project of China, including THU, PKU, BUAA, Tianjin University (TJU), Shanghai Jiao Tong University (SJTU), Huazhong University of Science and Technology (HUST), Northeastern University (NEU), Harbin Institute of Technology (HIT), Southeast University (SEU), South China University of Technology (SCUT), University of Science and Technology of China (USTC), Xi'an Jiao Tong University (SJTU). The case of SFT in this paper is one of 39 faculties within

BUAA, which is positioned as educating top-notch talents.

SFT undertakes the responsibility of leading engineering education reform at BUAA, having an eight-year Bachelor's directly to Doctor's degree program. The program is field-oriented rather than disciplined-based, that is, students do not have a specific major when they are enrolled in the program, they gradually clarify their research fields together with their university-industry mentor groups during eight years' learning. The program also offer flexibility for students to pursue a Bachelor's or Master's degree based on their own interests and career plannings. The first cohort of over 80 students are enrolled in 2021.

What sets the SFT program apart from other curriculum development initiatives is that it introduced and delivered a complete revision of engineering education across traditional disciplines. Students enter the SFT program without a specific major but share a common framework of project-centric and student-centric learning experiences via the integrative learning approach combing curricular learning, project experiences, and campus life. The curricular structure of the SFT program and its design reasoning is explained in the next section via the "why-what-who" framework.

## 4. The "STEP by STEP" Curricular Structure of the SFT program

In this section, we first introduce the underlying assumptions in curriculum design of the SFT program to clarify our arguments in responding to the calling for engineering education reform towards future, then the curricular construct titled "STEP by STEP" would be described, and finally, we briefly discuss the mentor groups who play an axial role in the curriculum.

### *4.1. Why and to what end: the breakthrough and remixing philosophy of curriculum design*

Engineering is more than knowledge (John et al.,2021), and engineers are usually creative and innovative in solving the world's most pressing problems (Borrego & Bernhard,2011). In consequence, engineering education are motivation for better preparing students to address these problems and future challenges. The goal of SFT is to prepare students to become future engineers with foresights to create, innovate, and lead technological advancement, therefore, curriculum design is central to achieve such goal. To cultivate these kinds of future engineers, the ways in which we design the curriculum need to change.

Perhaps facilitating multidisciplinary or interdisciplinary not only in engineering education but also in broader education, as well as the shift from classroom teaching to more student-centric and project-based learning has reached a consensus. While classroom teaching is an efficient approach to deliver discipline-based knowledge and methods, the effectiveness of high-level knowledge learning and required skills preparing for students is still being challenged (de Graaff et al.,2007). At the same time, the foundation of science and mathematics in engineering remains significant, the value of engineering design and practices, as well as communications and teamwork are still featured heavily. Therefore, the redesign of engineering education needs to borrow the idea of "engineering habit of mind" while our education preparing for engineers (Lucas & Hanson, 2016), which underpins the realistic point for the curriculum design of SFT program to balance scientific foundation, ever-complex engineering sciences, emerging technological trends, societal impacts, and students' own interests and needs. Accordingly, the philosophy encapsulated in the SFT program can be summarized as "breakthrough" and "remixing" while embedded in current curricular structure and educational traditions in engineering. This breakthrough and remixing philosophy underpinning the SFT curriculum to achieve its goal of promoting students' personality development with highly self-aware, transferable skills, and innovative foresights via producing a distinct and inclusive program.

*Breakthrough*. Increasing emphasis on communication and collaboration that involves multiple disciplines is generally assumed valuable and beneficial to higher education (Horn et al.,2023), however, there are differences in the involvement and interaction among such collaborations. Multidisciplinary cooperation is more discipline-based which draws on knowledge from different disciplines but still stays within traditional boundaries (Med,2016); interdisciplinarity integrates different disciplines into a new level of discourse and integration of knowledge, and transdisciplinary collaboration goes more beyond traditional boundaries that subordinate disciplines and provides holistic schemes via looking at the dynamics of whole systems (Klein,1990). However, the fact that cannot be ignored is no matter how engineering programs are structured to be multidisciplinary, interdisciplinary, or transdisciplinary, they still rely more or less on disciplinary courses, and the staffing of faculty lines are still in disciplinary departments (Knight et al., 2013). Therefore, we argue that the breakthrough of disciplinary boundaries might be an effective approach to facilitate real communications and collaborations between disciplines, as a result, the goals of SFT programs can be achieved while the initiative is juxtaposed with traditional disciplined-based engineering education.

*Remixing*. Only the breakthrough of disciplines cannot prepare students with systemic education including both knowledge and methods from basic science, mathematics, engineering science, humanities and social sciences. Traditionally, engineering education rely heavily on disciplinary knowledge and methods, especially an emphasis on science, mathematics and technical fundaments. In fact, researchers have claimed that engineering education was dominated with science since 1980s (Crawley et al.,2007). However, "learning is not just a matter of whether we can understand a scientific account, but also of whether our social and cultural options in life make it in our interests to do so" (Lemke, 2001), this particularly applicable for engineering education, and a trend of incorporating concepts from both technical disciplines and social sciences to offer students with more flexibility has been noticed in recent engineering education reforms such as the launch of CDIO and NEET at MIT. In this study, we argue that transcending traditional disciplinary boundaries needs rationales while redesigning the curriculum, breaking boundaries of disciplines but no scientific restructuring will lead our engineering education to be a brook without a source or a tree without a root, which might be against educational rules. Inspired by the idea of conceptualizing technology evolvement as a dynamic process of combining and structuring by Arthur (2009), as well as the idea of "remixing" Kelly (2016) used to describe one of the 12 technological forces that shape our future, Lu (2021) further borrows such idea into the field into education and asserts that remixing can be regard as philosophical foundation of educational reforms represented by NEE in China. Following the idea of technology evolvement, we argue that remixing knowledge and methods from various disciplines after transcending disciplines might be an accountable approach to redesign the curriculum, it is the knowledge and methods within real-world problems from the ever-changing emerging technologies rather than traditional disciplines that prepare our students with a remixing competency to flexibly create and innovate. As Arthur (2009) indicated, technology evolves through combining existing technologies to yield further technologies, thus, the innovation of technology can be visualized as new solutions within given technologies, novel technologies themselves, new bodies of technology, and new elements added to the collective of technology. Regarding curriculum design for SFT, it can be also considered as a spiral iteration process which connects knowledge and methods from not only different disciplines but also the continuous problem-solving process, this process includes fundamental knowledge and methods learning, knowledge and methods gained from the process of problem solving, cutting-edge knowledge themselves, and new knowledge and methods continuously accumulating to construct personalized knowledge and method "database". Therefore, the curricular features of SFT are marked by less reliance on traditional disciplines but more reliance on problems from technology evolvement, and the staffing line shifts from depending on disciplinary departments to depend on staffing roles and specific projects they enrolled in.

### *4.2 What: the curricular construct*

(1) Overall structure of the SFT curriculum

Curriculum represents the expression of educational ideas in practice (Prideaux,2003). In our context, curriculum is considered as the learning that is expected to take place during a program of study (McKimm,2007) - rather than a set of courses - which is developed from scratch but designed and implemented within existing institutional context and disciplinary constrains. The overall structure of the SFT curriculum can be seen in Figure 1. It shows a schematic representation of the SFT's curriculum featured by beyond disciplines, project-centric, and a successive baccalaureate to doctorate degree.

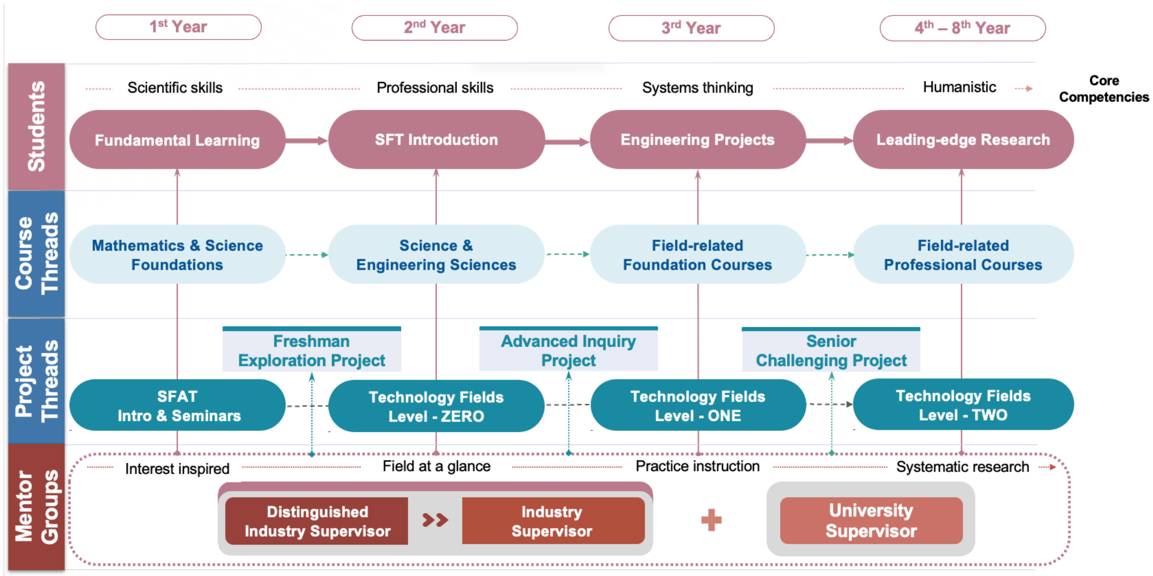


*Figure 1*. Overall structure of the SFT curriculum

Beyond disciplines. Although the SFT curriculum is designed within current disciplinary context, there is no specific disciplines or majors among the curriculum, students are enrolled in the "SFT program" rather than a specific discipline. The curriculum highlights the fields of technology, which are open and flexible to curriculum innovation and underpinning the projects and courses. It must be recognized that no clear discipline or major might bring confusions or doubts about the curriculum, especially for our first cohort of students and their parents. Therefore, the designing processes require careful and scientific demonstration to clarify the curricular philosophy, goals, and content of the curriculum. The resulting curriculum is thus going beyond disciplines that inserts leading-edge technologies and the cross-cutting knowledge and methods into traditional discipline-specific structure, as a result, it involves staff from different departments, different universities, and industry partners and allows them to engage with the ideas prior to educating today's and bring confidence to transform engineering education in the whole context of BUAA.

*Project-centric*. As Sheppard et al. (2008) indicated, engineering curriculum design should shift from a linear model to a spiral one with all components structured increasingly sophisticated and interconnected. The SFT curriculum therefore uses progressive projects as central themes for traction to organize courses, projects, and students' learning experiences together. In terms of curriculum connection, projects are juxtaposed with courses throughout curriculum rather than just upper-division courses that are independent from both fundamental and technical courses. In other words, what students learning are depended on the projects, which come from key topics in different levels of technology fields and are scientific reasoned by experts inward and outward the university. The projects are organized in a hierarchical structure allowing students to iteratively and autonomously undertake courses, acquire knowledge and develop skills. Through the strand of projects, students gradually clarify their interests in a more focused field which acts as a vehicle for students to make connections between theoretical learning and practical experiences, the process in which they are enrolled in allows students to be self-learners to construct their own body of knowledge. As a result, students' experiences can be integrated into the whole curriculum.

*Successive baccalaureate to doctorate degree*. The curriculum adopts a direct doctorate degree which allows a wide variety of options of knowledge and methods to be delivered, as a result, more flexibility around what students are going to learn can be identified. In freshman and sophomore years, students widely explore the technology fields before they are introduced into certain projects, which is achieved via introductory lectures, seminars, and innovative freshman exploration project, meanwhile they take restructured courses in science, mathematics, engineering science, humanities and social science to satisfy the prerequisites for project work; in junior and senior years, students substantially participate in the advanced inquiry project and senior challenging project with their mentor groups, they also select relevant professional courses across campus in-process of the projects, also, students may receive a bachelor degree most relevant to their projects and courses; in the doctoral years, students further concentrate on in-depth projects towards cutting-edge technologies with their mentor groups and will finally receive a doctorate degree. In addition, the flow design of the curriculum allows students to transfer to a specific discipline if they feel not interested or suitable for the SFT program, Bachelor's or Master's degree is also feasible for students who do not pursue doctorate degree. This direct doctorate degree setting contributes to addressing the dilemma of solid science fundamentals and sufficient engineering practices though a backward design to help students consider engineering as a wider scenario that needs a journey to reveal, create, and innovate.

(2) Course threads of the SFT curriculum ($S_1TE_1P$)

The course thread represents knowledge and methods remixed both within a certain or similar discipline and across the curriculum. Although considered as an innovative approach to break disciplinary boundaries, early on in the design process the course threads are still considered as combining courses from different engineering disciplines to teach fundamental technical subjects as usual. We note that discipline-specific contents - especially fundamentals in science and engineering sciences - remain important for students, therefore we introduce course threads to link similar disciplines with projects to remix knowledge and methods. This would be a collaborative process across campus, however, within the remixing process, departments are faced with challenges to restructure and update their existing disciplinary contents. To address this issue, we further introduce the "Professor in Charge" mechanism to facilitate innovations in structuring threads and designing courses. The term "thread" works out from perspectives of both course content and the instructors: firstly, knowledge and methods from similar disciplines or areas are remixed into interactive courses that together constitute a thread; secondly, the threads draw experts from disciplinary areas to be cooperative in redesigning and restructuring the course dominated by discipline-specific contents.

Currently, the SFT curriculum has established six course threads including Mathematics, Physics, Computing +, Electronics, Mechanics, and Humanity and Social Science (HSS), which can be seen in *Figure 2*. Each thread has a professor in charge who is responsible for the overall planning and organizing of courses within the thread, choosing appropriate instructors, facilitating redesign of syllabuses, dedicating to improving quality of courses and innovating pedagogies, as well as compiling textbook and materials. The professors and instructors are not limited in one discipline or university, they contribute their strengths and coordinate together to design the course thread. It should be noted that although titles of the courses look similar as usual, the way they were addressed and the contextual nature of the subject within the courses are considerably different – knowledge and methods are totally remixed.

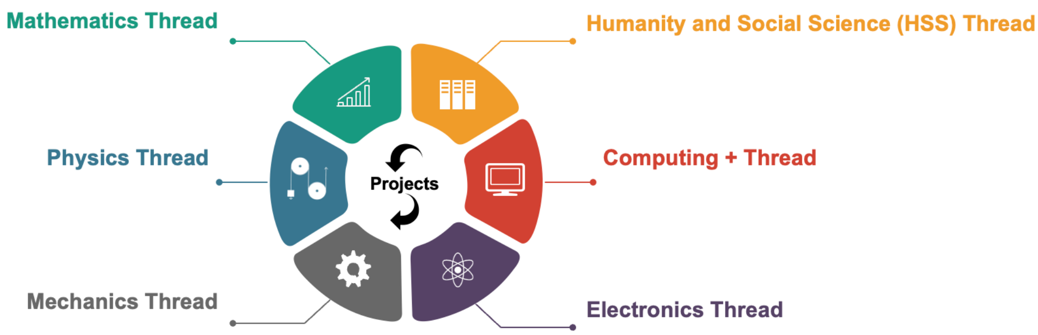


*Figure 2*. Course threads of SFT curriculum

(3) Project thread of the SFT curriculum ($S_2TE_2P$)

The centerpiece of SFT curriculum is the project threads, which represent progressive projects including freshmen exploratory project, advanced inquiry project, and senior challenging project, the project threads run through all disciplines and are interconnected with the course threads.

Project-based learning and its variants have been identified as a common curriculum strategy (Mills & Treagust,2003), pioneers such as Aalborg University includes projects into coursework towards practical industry problems to highlight learning rather than teaching (Kolmos,1996). It is widely credited with a number of benefits including fulfil industry needs (Uziak,2016), facilitate skills such as technical and interpersonal competences, problem-solving, collaborative learning, and interdisciplinarity (de Los Rios et al.,2010; Gavin,2011; MacLeod & van der Veen,2020), and is prescribed as an ideal technique to change the “chalk and talk” pedagogy in engineering. However, we note that these endeavors are still in certain specialty areas, and to some extent separate from courses and students' whole learning experiences. Therefore, we shift traditional project-based learning to project-centric to highlight the spine role of projects in engaging students in real-world problems within the development of technologies, this change brings together a range of topics towards ever-emerging technologies, and followed up with certain project-relevant courses throughout students' whole campus experiences. As a result, a "STEP by STEP" curricular structure, combing with the remixing ideology is formed with project threads working as central to connect the curriculum, as well as students' distinctive learning experiences (*Figure 3.*).

In the context of "Step by Step" curricular construct, not only multiple disciplines are integrated and restructured but also students' learning experiences are inserted, as a result of which the curriculum is designed to be remixed by individual that allows distinctive interpretations of the curriculum. At present, three progressive projects are designed drawing on key topics around leading-edge technologies including the freshman exploration project, advanced inquiry project, and senior challenging project. Following each project, related courses combing students' interests and the project's requirement can be chosen. Two distinct roles of the project threads can be identified: firstly, project threads are spine of the curriculum that connect projects, courses, and students' experience to be substantially project-centric and student-centric; secondly, project threads work as axis of university-industry cooperation that bring the industry closer not only to students but also to faculty within the university. Around the carefully designed projects, mentor groups and students work together, not only striving to students training but also facilitating cooperation in research, to overcome barriers possibly exist in university-industry cooperation such as conflicts in the orientation of research and a lack of inter-organizational trust (Tartari et al.,2012; Lopes & Lussuamo,2021).

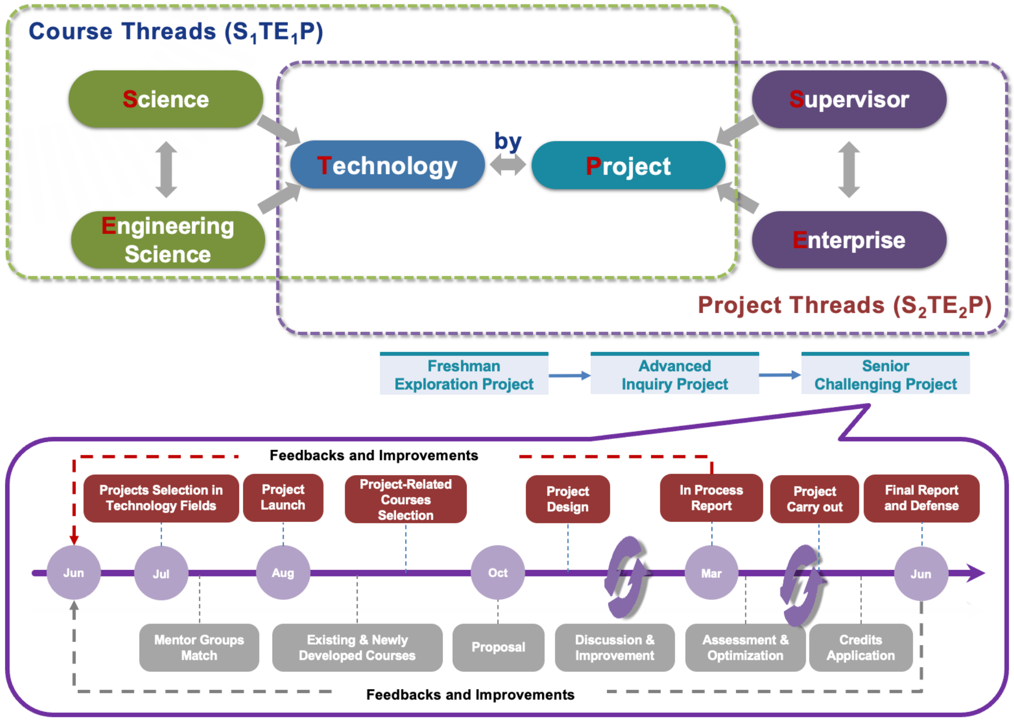


*Figure 3*. Generic of project threads in SFT curriculum

### *4.3 Who: mentor groups and students as a community*

Different from general industry-based mentoring and cooperative education approach to bridge the gap between theory and practice in engineering education, the mentor groups in the SFT curriculum play significant role in building stronger relationships with industry and students. Traditionally, a wide variety of forms have been taken in university-industry cooperation through diversified interaction channels such as service and bi-directional research (Gulbrandsen et al.,2011), however, the interface between motivations of academics and the technological staff in industry to engage in university-industry cooperation remain unclear. At the same time, new developments in industry needs, student interests and their increasing self-learning ability as digital natives, and the increasing callings for pedagogical innovations in engineering education can be identified. Thus, we introduce mentor groups as a community combing university academics, industry staff, and students for two purposes: innovate university-industry cooperation channel so as to contribute to high-quality research and teaching, and engage students in up-to-date research so as to facilitate the development of remixing competency and holistic development.

The mentor groups for students include a distinguished industry supervisor who is usually a chief engineer in industry, an industry supervisor among the distinguished supervisor's team, and one university supervisor whose research field is similar or complementary with the industry supervisors. To consider university-industry cooperation in terms of mentor groups, advantages from both sides should be strengthened. University supervisors generally have rich pedagogical content knowledge on teaching and learning in their specialty areas, and are emotionally invested in engineering educational settings (Borrego & Newswander, 2008). Regarding the industry experts, who might find their practical approaches are not as suitable for educational activities when engaged in the SFT curriculum, while they provide tacit knowledge about ‘‘know-how’’ and put ‘‘know-what’’ into practice (Brown & Duguid, 1998). Therefore, views of industry supervisors around the frequent and rapid changes in technology, as well as issues from the up-to-date research and practices in industry can be brought into teaching via mentor groups, as a result of which, not only knowledge and expertise related to "know-how" can be learned by students but also their beliefs, values, and cognitions can be imperceptibly transferred to students. This can be achieved because the mentor groups are not just engaged in educational activities, they are bi-directional contributed community and rallied around collaborative research projects to jointly promote innovation.

Another important character of our mentor groups is that students are also gradually engaged in the innovation community. They are not only flexible and imaginative learners with passion, fresh insights, and curiosity, but also participators, contributors, and promotors in collaborative projects. It is the projects that plays a networking role to well connect insights from industry and university across organizational boundaries and disciplinary boundaries via formal and informal cooperation, therefore, innovations on longer remain in academic disciplines with their own body of knowledge benefit of such community. Regarding the students, they are able to integrate their curricular learning and project experiences to improve their systematic learning experiences and facilitate holistic development. However, an approach is needed when engaging students in the community, in this sense, we introduce the integrative learning to help the development of students' remixing competence in terms of integrating university-industry cooperation and students' regular curricular structure. Integrative learning considers the flexibility and mobility of learning in the knowledge society, aiming at facilitating the competence of connecting and integrating, as well as the passion in learning with a more intentional, deliberative, and reflexive stance (Huber & Hutchings,2004). We argue that new areas of knowledge are continuously emerging beyond disciplines, knowledge practices and innovations are constantly transforming by technologies, students we educate today would benefit from having a competence to make connections among concepts and experiences, and remix knowledge and methods from different disciplines to apply them through real-world engagements. Therefore, students must play a key role to make integrative leaning happen with in-depth commitment and engagement, the SFT curriculum develops a new kind of scaffolding that allows students going beyond a particular discipline and focusing on discovery and creativity towards future technologies with their mentor groups to distinctively connect their curricular learning, project experiences, and campus and community life.

## 5. Conclusions

This paper provides a shortcut into the case of SFT at BUAA in delivering an innovative and pilot engineering curriculum towards future featured by transcending disciplines in the context of existing disciplinary structures with the breakthrough and remixing philosophy. It interprets the rationale for design of the "STEP by STEP" curricular construct and how students and mentor groups are engaged in collaborative research projects. Different from current multi-, inter-, and transdisciplinary engineering curriculum design, the SFT program at BUAA adopts an approach to jump directly out of boundary of disciplines and use key topics and themes within fields of technology as evidence to reflect and remix knowledge and methods for technological development. A key point of learning from the curriculum design of SFT is that helping students develop competence for going beyond discipline-specific curricular fragmentation and remixing their own knowledge hierarchy and abilities is becoming a priority for universities today, a scaffolding that connects courses, projects, and students learning experience is needed to make students in the knowledge and information society to be more self-awarded and self-directed learners and contributors. In addition, we argue that although more efforts and cognitions maybe needed to finally implement, this curricular structure can be co-existed with traditional discipline-specific curricula within one university that is more realistic to facilitate curricular reforms in engineering education.

## 6. Future opportunities

Scaling up engineering education reforms globally brings not only challenges but also opportunities, the SFT curriculum at BUAA is not meant to be exhaustive and exclusive in terms of curricular reforms in engineering education in China. The tale of SFT curriculum design can be interpreted through diverse lenses, it can be read as confirming both solid foundation of science and mathematics and real-world practice experiences, also, it can be considered as a potential initiative to institutionalize interdisciplinary engineering education while achieving the reform visions and desired educational goals. We definitely embrace more innovative designs in both SFT and whole landscape of engineering education, particularly those not well addressed in the SFT curriculum, so that educators and practitioners might better understand and contribute to best practices that inform engineering education. Engineering curriculum design is no easy feat that requires diverse approaches and strategies from both faculty and students in university and experts in industries. Moreover, we also need global dialogs to share best practices and perspectives.

## Acknowledgement

The authors are grateful to all the staff and students enrolled in the SFT program at BUAA for their commitment and dedication to the program. We would like to thank Beijing Municipal Education Commission for supporting this project through the Project of Undergraduate Teaching Reform and Innovation "Exploration of a new Paradigm of the Top-notch Innovative Talents Cultivation for Future Science and Technology." The views in this paper are those of the authors and do not necessarily represent those of the Beijing Municipal Education Commission. We also sincerely acknowledge the critical feedbacks from the chair and reviewers of ASEE.

## References


Arthur, W. B. (2009). The nature of technology: What it is and how it evolves. New York, Simon and Schuster.

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

Borrego, M., & Newswander, L. K. (2008). Characteristics of successful cross-disciplinary engineering education collaborations. Journal of Engineering Education, 97(2), 123–134.

Brown, J.S., & Duguid, P. (1998). Organizing knowledge. Californian Management Review, 40(3), 90-111.

Cai, Y.H., & Ding F.J. (2019). From Ability Development to All-Round Development: Research on the Strategies of Curriculum Construction and Curriculum Implementation of General Education in New Engineering, China Higher Education Research, (10):75-82.

Crawley, E. (2015). The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education. Cambridge, MA: Worldwide CDIO Initiative.

Crawley, E. F., & Hosoi, A. E. (2019). Moving Forward with the New Engineering Education Transformation (NEET) program at MIT-Building community, developing projects, and connecting with industry. In 2019 ASEE Annual Conference & Exposition, Tampa, Florida.

Crawley, E. F., & Hosoi, A. P., & Mitra, A. B. (2018). Redesigning undergraduate engineering education at MIT–the New Engineering Education Transformation (NEET) initiative. In 2018 ASEE Annual Conference & Exposition, Salt Lake City, Utah.

de Graaff, E., Markkula, M., Demlová, M., Kuru, S., & Peltola, H. (2007). Innovative learning and teaching methods. In C. Borri & F. Maffioli (Eds.), TREE: Teaching and research in engineering in Europe: Re-engineering engineering education in Europe (pp. 51–64): Firenze, Italy: Firenze University Press.

de Los Rios, I., Cazorla, A., Díaz-Puente, J. M., & Yagüe, J. L. (2010). Project–based learning in engineering higher education: two decades of teaching competences in real environments. Procedia-Social and Behavioral Sciences, 2(2), 1368-1378.

Fu, Y.Z., & Liu, T. (2020). iFabLab: A Novel Action-Learning Model Based on New Engineering Education, Research in Higher Education of Engineering, (5),30-36.

Gavin, K. (2011). Case study of a project-based learning course in civil engineering design. European Journal of Engineering Education, 36(6), 547-558.

Goodlad, J. I. (1979). Curriculum Inquiry: The Study of Curriculum Practice, McGraw-Hill, New York.

Gulbrandsen, M., Mowery, D., & Feldman, M. (2011). Introduction to the special section: Heterogeneity and university-industry relations. Research Policy, 40(1), 1-5.

Guo, Y. C. (2021). Engineering Design Thinking in the New Engineering Curriculum, Research in Higher Education of Engineering, (1),39-43+55.

Hadgraft, R. G. (2017). Transforming engineering education: Design must be the core. In Proceedings of the 45th SEFI Annual Conference 2017-Education Excellence for Sustainability, SEFI 2017.

Han, T., Guo, H., Yin, S., & Zhang, R. (2019). An Empirical Study on the Impact of Project-Based Learning on the Development of Engineering Practice Competence of College Students, Research in Higher Education of Engineering, (6),65-72.

Horn, A., Scheffelaar, A., Urias, E., & Zweekhorst, M. B. (2023). Training students for complex sustainability issues: a literature review on the design of inter-and transdisciplinary higher education. International Journal of Sustainability in Higher Education, 24(1), 1-27.

Hotaling, N., Fasse, B. B., Bost, L. F., Hermann, C. D., & Forest, C. R. (2012). A quantitative analysis of the effects of a multidisciplinary engineering capstone design course. Journal of Engineering Education, 101(4), 630-656.

Huang, T.Z., Huang, Y., & Xiang, G.J. (2022). Addressing the Dilemma of “Large-Scale Accountability” in Engineering Education Reform, China University Teaching, (9),46-51.

Huber, M. T., & Hutchings, P. (2004). Integrative Learning: Mapping the Terrain. The Academy in Transition. Association of American Colleges and Universities.

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

John, E.M., Abel, N., Kate, R., & E., Tilley. (2021) Faculty wide curriculum reform: the integrated engineering programme, European Journal of Engineering Education, 46(1),48-66.

Kelly, K. (2016). The inevitable: Understanding the 12 technological forces that will shape our future. London, Penguin.

Kerns, S. E., Miller, R. K., & Kerns, D. V. (2005). Designing from a blank slate: The development of the initial Olin College curriculum. In Educating the engineer of 2020: Adapting engineering education to the new century, 98-114.

Klein, J.T. Interdisciplinarity: History, Theory, and Practice. Detroit: Wayne State University Press, 1990.

Knight, D. B., Lattuca, L.R., Kimball, E.W., & Reason, R.D. (2013). Understanding interdisciplinarity: Curricular and organizational features of undergraduate interdisciplinary programs. Innovative Higher Education, 38, 143-158.

Kolmos, A. (1996). Reflections on project work and problem-based learning. European journal of engineering education, 21(2), 141-148.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. Journal of Research in Science Teaching, 38(3), 296–316.

Li, C., Mao, W.W., & Sun, J. The New Industrial Revaluation and Curriculum Reform: Construction Pathway of New Engineering Curriculum Based on the Transformation of Knowledge Production, China University Teaching, (7),88-96.

Li, M. L. (2010). The Unique Cultivation of Exemplary Engineering Innovators: The Educational Ideas and Practices of Olin College of Engineering. University Education Science, (2),91-96.

Lin, J. (2017). The Construction of China’s New Engineering Education Towards Future. Tsinghua Journal of Education, 38(2),26-35.

Lin, J. (2021). Construction of the School of Future Technology: The Cultivation of Future Technical Leading Talents, Tsinghua Journal of Education, 42(1),40-50.

Liu, J., Wang, L.Y., Shi, L.X., & Lu, W.J. (2021). On Curriculum System of New Engineering Education Transformation in Massachusetts Institute of Technology. Research in Higher Education of Engineering, (6),140-145.

Lopes, J., & Lussuamo, J. (2021). Barriers to university-industry cooperation in a developing region. Journal of the Knowledge Economy, 12(3), 1019-1035.

Lu, G.D., Zhao, Y., & Zhao, C.Y. (2018). Research on the Path of Training Engineering Talents Based on Ground

Theory. Research in Higher Education of Engineering, (5),58-64.
Lu, X.D. (2021). Remixing: The Emerging Engineering Programs and Education on the Horizon of Technology Evolution and Revolution, China Higher Education Research, (7):20-28+41.
Lucas, B., & Hanson, J. (2016). Thinking Like an Engineer: Using Engineering Habits of Mind and Signature Pedagogies to Redesign Engineering Education. Int. J. Eng. Pedagog., 6, 4-13.
Luo, J.Q., Ye, X., Liu, P.F., & Chen, W.Y. (2020). Freshman Engineering Cognitive System Construction in New Engineering: Take the CS Introduction Course as An Example. Research in Higher Education of Engineering, (5),25-29.
Maciejewski, A. A., Chen, T. W., Byrne, Z. S., De Miranda, M. A., Mcmeeking, L. B. S., Notaros, B. M., ... & Notaros, O. (2017). A holistic approach to transforming undergraduate electrical engineering education. IEEE, 5, 8148-8161.
MacLeod, M., & van der Veen, J. T. (2020). Scaffolding interdisciplinary project-based learning: a case study. European journal of engineering education, 45(3), 363-377.
McKenzie, L. J., Trevisan, M. S., Davis, D. C., & Beyerlein, S. W. (2004). Capstone design courses and assessment: A national study. In Proceedings of the 2004 American Society of Engineering Education Annual Conference & Exposition (pp. 1-14).
McKimm, J. (2007). Curriculum design and development. Medical Education, 1-32.
Med, C. I. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. Clin Invest Med, 29(6), 351-364.
Mills, J. E., & Treagust, D. F. (2003). Engineering education—Is problem-based or project-based learning the answer. Australasian journal of engineering education, 3(2), 2-16.
Ministry of Education. (2021). Announcement for First Establishing 12 SFTs, [Online]. Available at: http://www.moe.gov.cn/srcsite/A08/moe_742/s3860/202105/t20210526_533701.html, [Accessed: 29-Jan-2023]
Mitchell, J. E., Nyamapfene, A., Roach, K., & Tilley, E. (2021). Faculty wide curriculum reform: the integrated engineering programme. European Journal of Engineering Education, 46(1), 48-66.
Prideaux, D. (2003). ABC of learning and teaching in medicine. Curriculum design. BMJ, 326(7383),268–270.
Reymen, I., Bruns, M., Lazendic-Galloway, J., Helker, K., Cardona, A.V. and Vermunt, J.D. (2022). Creating a Learning Ecosystem for Developing, Sustaining, and Disseminating CBL the Case of TU/e Innovation Space Vilalta-Perdomo, E., Membrillo-Hernández, J., Michel-Villarreal, R., Lakshmi, G. and Martínez-Acosta, M. (Ed.) The Emerald Handbook of Challenge Based Learning, Emerald Publishing Limited, Bingley, pp. 13-33.
Sheppard, S.D., Macatangay, K., Colby, A., & Sullivan. (2008). W.M. Educating Engineers: Designing for the
Somerville, M., Anderson, D., Berbeco, H., Bourne, J. R., Crisman, J., Dabby, D., ... & Zastavker, Y. (2005). The Olin curriculum: Thinking toward the future. IEEE Transactions on Education, 48(1), 198-205.
Tartari, V., Salter, A., & D'Este, P. (2012). Crossing the Rubicon: Exploring the factors that shape academics' perceptions of the barriers to working with industry. Cambridge Journal of Economics, 36(3), 655–677.
Tian, H., Liu, D.B., & Han, T. (2021). The Design and Implementation of PBL Course Teaching Under the Context of New Engineering Education, Research in Higher Education of Engineering, (4),59-65.
Urde, M., Greyser, S. A., & Balmer, J. M. (2007). Corporate brands with a heritage. Journal of Brand Management, 15, 4-19.

Uziak, J. (2016). A project-based learning approach in an engineering curriculum. Global Journal of Engineering Education, 18(2), 119-123.

Wang, G.Q. (2021). Construction of General Education System in New Engineering Based on the Outcome-Based Education, Research in Higher Education of Engineering, (4),29-34.

Wei, S., Ohland, M., & Zheng, L. (2022). New Engineering Education initiative of China: A Policy Debrief Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN.

Wilbarger, J., & Howe, S. (2006). Current practices in engineering capstone education: Further results from a 2005 nationwide survey. In Proceedings. Frontiers in Education. 36th Annual Conference, IEEE, 5-10

Wu, A.H., Hou, Y.F., Yang, Q.B., & Hao, J. (2017). Accelerating New Engineering Education and Initiative to Adapt and Lead the New Economy, Research in Higher Education of Engineering, (1),1-9.

Wu, J.S., & Zou, X.D. (2013). Regression to Engineering Practice: A Preliminary Exploration into the Reform Model in Olin College of Engineering. Research in Higher Education of Engineering, (1),40-45+70.

Xiao, F.X., & Tan, L.J. (2018). Research on the Formation, Content and Internal Logic of New Engineering Education Reform at MIT. Research in Higher Education of Engineering, (2),45-50.

Ye, J.X, Han, Y., Zhang, J.L., & Liu, K.S. (2022). Exploring the Construction of School-Enterprise Collaboration Mechanism for Education and Cultivation of Outstanding Engineers in the New Era: Taking School of Future Technology of Beihang University as an Example. China Higher Education Research, (6):50-56.

Zeng, Y., Huang, Y., Xiang, G.J., & Huang, T.Z. (2020). Design and Practice of UESTC-New $E^3$ Plan for the New Engineering: Starting from the Freshman Project Courses, Research in Higher Education of Engineering, (1),14-19.

Zhou, L., Fan, L.X., Fan, H.M., & Li, J.X. (2021). Curriculum Construction in the Era of "New Engineering": Based on an Empirical Investigation of Core Competency, Renmin University of China Education Journal, (3),52-77.