CHAPTER 5

Innovation Education in China: Preparing Attitudes, Approaches, and Intellectual Environments for Life in the Automation Economy

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The Ninth Five-Year Plan explicitly made reform aimed at improving the quality of education a core priority.[1] Since then China has allocated an ever-increasing percentage of its budget to education; in 2015 that expenditure reached 4.26% of the country's GDP. Ten years ago, the effort focused on the basics—infrastructure and faculty hiring. At the university level, this meant building better labs, hiring more faculty, updating and improving buildings, and so on. Five years ago, as more Chinese middle-class parents began to send their children abroad for school, universities and high schools began to focus more closely on content and curriculum. Popularization of the 'Tiger Mom' in the United States with its

[1] In 1999, the 3rd National Conference on Education was held where the goal of promoting quality-oriented education (as opposed to exam-oriented education) and innovative capacity was raised.

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accompanying sense of insecurity about the rigor of US education stimulated an oddly complementary reaction in China in the form of an insecurity about the adequacy of China's education in the twin realms of creativity and innovation. Countries worldwide realized that the main sources of job growth would come through innovation and entrepreneurship. The pressure was felt most strongly in the education sector.

The Chinese response to the need to create a culture of innovation and entrepreneurship has been significant. In a few short years, the phrase 'Chinese Innovation' has gone from meaning copying Silicon Valley to fears of China surpassing Silicon Valley. Every day, we read another case study about Chinese innovation, the omnipresence of weChat, China's leading position in mobile payments, fintech, Alibaba, and China's emergence as a leader in fields such as artificial intelligence and machine learning. The challenge that remains here, however, is maintaining the momentum and that involves creating a culture, or ecosystem (生态), of creativity, critical thought and entrepreneurial spirit. These environments are created by practices developed early in life and deeply influenced by the social, economic, and educational institutions young people and young adults come into contact with. No institution is more important to developing a culture of creativity and innovation than school. In China, this has led to a fundamental revamping of its educational system. This is a grand project requiring sustained effort and persistence. It is also a project that requires a reset of 'software' (i.e., attitudes, approaches, and intellectual environment).

China's success at modernizing over the last 30 years has followed a consistent pattern comprising investigation of best-in-class models from other countries, experimentation in China (usually involving a wide range of permutations and varying degrees of localization), and then mass adoption through government edict or market demand. In this chapter, we describe the state of current higher educational reform efforts in support of innovation; explore the obstacles facing far reaching reform, offer a view about the likelihood of success, and the potential emergence of a 'Chinese model' for innovation; and identify some lessons other countries might draw from China's experience. We use our own experience, introducing and teaching 'Design Thinking' to STEM students at a Chinese university as a case study.

Innovation Education in China

Innovation: A Buzzword in China and Its Intersection with Education

At the 2014 Davos Forum, Premier Li Keqiang introduced the slogan 'Mass Entrepreneurship and Innovation' and by 2015, innovation and entrepreneurship had been officially celebrated as an important part of national policy (e.g., the word 'maker' appeared in government report in March 2015).[2] Statistically, China can take pride in its progress since the formal invocation in 2015. The Global Innovation Index ranks China at 25 in 2016, scoring at 50.60.[3] This marks a material change compared to its rank of 29 with a score of 47.47 in year 2015.[4] The Report of National Innovation Index 2016–2017[5] rates China at 17 among the 40 countries it investigates (compared to 19 in 2014), a leading position in the second tier, a meaningful improvement in a short time.

It is impossible to appreciate or explain the nature of China's investment in developing a culture of innovation and creativity while ignoring the fact that China is fundamentally a centrally planned economy. For national priorities, the Central Government disburses funds to the provinces and so on to the smallest administrative unit. Thus, one can observe even the smallest district in China encouraging 'Ten Thousand types of Entrepreneurship and Innovation' (万众创新) as manifested in the mushrooming number of fab labs, makerspaces, co-working spaces, hackerspaces, incubators, and accelerators. Lego classes for creativity and hackathons occur multiple times per day all over the country.

Our focus here is on the development of this culture in universities across China. In keeping with the government mandate, universities across the country have created new schools dedicated to innovation named

[2] Tsinghua University, Modern Educational Technology, Intel Corporation, "Zhongguo chuangke jiaoyu lanpishu" [China Maker Education Bluebook 2015], 2015, https://www.intel.cn/content/dam/www/public/cn/zh/pdfs/csr-maker-education-2015-bluepaper.pdf.

[3] "Indicator Rankings and Analysis," The Global Innovation Index, accessed January 10, 2018, https://www.globalinnovationindex.org/analysis-indicator.

[4] The Global Innovation Index, "Indicator Rankings and Analysis."

[5] Chinese Academy of Science and Technology for Development, "Guojia chuangxin zhishu baogao 2016–2017 tujie" [National Innovation Index 2016–2017 Infographic], last updated August 8, 2017, http://www.casted.org.cn/channel/newsinfo/6336. The Academy has been issuing annual reports on national innovation index since 2011.

'School of Innovation,' 'School of Innovation and Entrepreneurship,' or 'School of Entrepreneurship and Management,' both within and out of extant business schools. The number of incubators has increased by 18% with 20% more space. Meanwhile, funding for innovation and entrepreneurship within and out of university has reached RMB 1.02 billion and RMB 1.28 billion respectively. More than 3 million university students are engaged in entrepreneurship and innovation events.[6] Conferences on innovation and entrepreneurship are hosted at universities multiple times per week. Here we see the first example of following well-trod paths from existing innovation ecosystems: using Silicon Valley (including Stanford), Israel's Technion, and MIT as models, the first prong of China's efforts focuses on the hardware supporting innovation. The underlying principle can be summed up as: If you build it, they will come.

Chinese universities have also initiated efforts to cultivate connections between universities and industry. Looking again to the example of US universities, Chinese universities undertake these partnerships to facilitate innovation moving from basic bench research to commercial application. They have created Tech Transfer offices that liaison with industry. New policies governing faculty inventions are being considered as is the challenge of allocating Intellectual Property (IP) ownership created by government funding.

From a policy perspective, the Ministry of Education (MOE) has issued specific policies to support innovation and entrepreneurship, including a policy allowing students to take one year off to pursue an entrepreneurial venture.[7] In 2015, the MOE suggested all universities provide eligible courses in entrepreneurship for credit (compulsory and selective) to all students.[8] By 2016, 82% of Chinese universities had introduced compulsory and elective courses in innovation and entrepreneurship (an increase

[6] The statistics were provided by Mr. Wang Lin from the Ministry of Education (China) at the International Forum on Innovation and Entrepreneurship Education at Renmin University of China, Beijing in October 2015.

[7] Ministry of Education China, "putong gaodeng xuexiao xuesheng guangli guiding" [Regulations for Ordinary Institutions of Higher Learning], February 16, 2017, http://www.moe.gov.cn/srcsite/A02/s5911/moe_621/201702/t20170216_296385.html.

[8] Ministry of Education China, "jiayubu guanyu zuohao 2016 jie quanguo putong gaodeng xuexiao biyesheng jiuye chuangye gongzuo de tongzhi" [Notice from the Ministry of Education regarding jobs and entrepreneurship for graduates from Ordinary Institutions of Higher Learning in 2016], December 1, 2015, http://www.moe.edu.cn/srcsite/A15/s3265/201512/t20151208_223786.html.

of 14% compared to the previous year). Similar reform efforts and investments in the spheres of vocational education and the equivalent of community colleges are also ongoing in China. Innovation education and its accompanying activities are occurring at every level of post-secondary education.

Finally, over the past eight years, the MOE encouraged Sino-foreign joint ventures between universities, as well as the establishment of private universities. These new players introduce new thinking, new systems, and new pedagogy into the DNA pushing local institutions to experiment and change. NYU Shanghai,[9] Duke Kunshan, Carnegie Mellon's efforts with Sun-Yat Sen, and Kean are among the more well-known recent efforts. Johns Hopkins' program with Nanjing University is the oldest existing program in China. While these initiatives are important, the balance of our discussion focuses on efforts within traditional institutions of higher education—Chinese research universities.

Observations on Two Curricular Trends in Support of Innovation

Investing in space, partnerships, and conferences is one thing. Adjusting curriculum and pedagogy is another kind of animal entirely. Teaching and applying innovation is not simply a 'lessons taught-skills acquired' process. Nurturing innovative capacity requires long-term and sustained efforts. We have noticed two related trends within Chinese universities that may have an impact on improving student capacity for innovative thinking.

The first noticeable trend is the renewed attention and trend toward 'general education' (通识教育).[10] Institutions such as Tsinghua University, PKU, and Zhejiang University (to name just a few) have liberal arts programs designed to give students a strong foundation in critical thinking and analytical skills as well as broaden students' mind.[11] Ironically, this takes place at the same time when the United States shows signs of turning away from liberal education. Fareed Zakaria in his book *In Defense of a*

[9] The author, Rosaline May Lee, spearheaded this project as Vice-Chancellor for Asia at NYU.

[10] This term is often used synonymously with liberal education and quality-oriented education, the latter is more widely applied in the context of elementary and middle-level education.

[11] See Appendix A for examples of such programs.

Liberal Education makes a case for revitalizing and reemphasizing liberal education, as a method to teach one how to write, how to speak your mind, and how to learn rather than simply empowering one with expertise knowledge and professional skills. He quotes Drew Faust, President of Harvard University, in which a "liberal education should give people the skills that will help them get ready for their sixth job, not their first job."[12]

According to the Association of American Colleges and Universities (AACU), the goal of a liberal education is to "help students develop a sense of social responsibility, as well as strong and transferable intellectual and practical skills such as communication, analytical and problem-solving skills, and a demonstrated ability to apply knowledge and skills in real-world settings."[13] While China's leadership has expressed a desire to instill social responsibility and innovative thinking in its students, it is unclear if the Chinese model will follow the Western tradition with its educational philosophy of breaking boundaries, cultivating a humanistic vision, and strengthening intellectual capabilities. In the West, this occurs through the close reading of text, robust disagreement, and intense (if respectful) questioning of authority under the guidance of a professor. It is difficult to read text closely, for example, when the text itself is controlled as is often the case here in China.

Coupled with the initiatives to inculcate the DNA of liberal education into undergraduate education, encouraging interdisciplinary research and study has also become popular. It is viewed as an essential feature of liberal education, but of course, this is no panacea to the challenge of teaching innovation. The same critique can be applied to offerings of new courses and degrees in correspondence with technological revolutions that are taking place. For instance, universities around the world have started to provide courses, degrees, and certificates in areas of data science (big data) and machine learning.[14] There is a danger, however, that these responses might overshadow the more long-term and essential goal of nurtureing the fundamental qualities required to innovate, including critical thinking, imagination, readiness for change, open-mindedness, and a high tolerance for uncertainty and resilience.

[12] Fareed Zakaria, *In Defense of a Liberal Education* (New York: W.W. Norton, 2015), 75.

[13] "What is a Liberal Education?," Association of American Colleges and Universities, accessed January 10, 2018, https://www.aacu.org/leap/what-is-a-liberal-education.

[14] Ryan Swanstrom, "Colleges with Data Science Degrees," April 9, 2012, http://101.datascience.community/2012/04/09/colleges-with-data-science-degrees/.

At this point, we switch our focus to exploring the ways in which the government mandate, which requires a culture of innovation and creativity, has played out in our experience in the School of Entrepreneurship and Management at ShanghaiTech University.

Case Study: Teaching Design Thinking in a Chinese University

We set our case study against such background, as ShanghaiTech is itself a brand-new university born out of the above trends.[15] The university eschews traditional departments in favor of broad-based schools. For example, the School of Physical Sciences includes the disciplines of physics and chemistry as well as many of the corresponding interdisciplinary sub-disciplines such as materials sciences and nanomaterials. Our students must take a broad range of compulsory courses in the humanities and social sciences. Each summer, students must engage in an experiential learning project.

Our journey of teaching 'Design thinking: Applied Innovation' demonstrates the potential and difficulties of launching innovation education in China. It also offers lessons in how innovation education might be adapted to specific contexts. More significantly, we share our reflections on how our observations can offer insight into China's preparation for the fourth industrial revolution (4IR) and whether China can innovate in a way that promotes future economic growth and employment.

Why Design Thinking?

The origin of 'design thinking' as a distinctive field of enquiry or subject can be traced to Herbert Simon and Robert McKim. Thereafter, a variety of architects and designers began to explicitly examine, analyze, and explain the methodology of design. Eventually, a group of designers drew a connection between the theory of design thinking to the idea of 'wicked problems' as a prominent feature of social enquiry.[16] Wicked problems are those issues that

[15] The university website states "the University seeks innovative solutions to address the challenges that China is facing in the field of energy, material, environment, human health, thus to improve productivity driven by innovation, and contribute to the restructuring and development of China."

[16] Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a general theory of planning," *Policy Sciences* 4, no. 2 (1973): 155–169.

cannot be readily defined and exhibit high level of complexity, interconnectedness, multiplicity, and fluidity. These problems, therefore, cannot be tackled with traditional linear scientific methods and they do not lend themselves to singular 'correct' solutions.[17]

David Kelly, co-founder of IDEO and founding dean of Stanford's d.school is credited with popularizing design thinking. Over the past two to three decades, design thinking has been taught to students from diverse disciplines with the aim of developing a set of capabilities to tackle large intractable social problems. Indeed, more and more, people use design thinking as a proxy or synonym for innovation. *Harvard Business Review* dedicated the September issue of the 2015 to design thinking and in his article 'Design Thinking Comes of Age,' Jon Kolko heralds design thinking "as an essential tool for simplifying and humanizing. It cannot be extra; it needs to be a core competence."[18]

Four years ago, in my capacity as the Dean of the School of Entrepreneurship and Management, I recommended we incorporate design thinking as a core curricular requirement. At the time, design thinking had yet to arrive to China's shores. ShanghaiTech was the only university in China to mandate such a course and we have made it a centerpiece of our effort to educate innovative talents.

Our initial goals for the course were:

1. offering the students an experiential-based course to learn the human-centered design process;
2. expose the students to real-world problems;
3. provide the students with an entry point for thinking about innovative approaches to problem-solving in business settings.

The ultimate goal of our course is ambitious, that is, to plant an innovation or entrepreneurial seed in these science and engineering students among whom some might become leaders, entrepreneurs, policymakers, or play other key roles in promoting innovative business and enterprises using 4IR technology, with the mission of bringing about true innovation and a sense of social responsibility.

[17] For an abbreviated but interesting history of design thinking, you can consult Natasha Jen, "Design Thinking is Bullshit," filmed 2017 at 99 U Conference, New York, New York, video, 13:27, http://99u.com/videos/55967/natasha-jen-design-thinking-is-bullshit.

[18] Kolko, "Design Thinking Comes of Age," *Harvard Business Review*, September 2015, https://hbr.org/2015/09/design-thinking-comes-of-age.

(Re) Learning the Localization Lesson

Initially, we offered Stanford d.School's standard syllabus (with a few concessions to local context) and immediately faced a number of challenges. The students' attitude toward the course posed the initial obstacle. Their reactions ranged from 'Why do I need to study design?' to 'What a terrible waste of time.' While students often have this reaction to mandatory core courses, we find more cause for concern from the results of an informal learning assessment at the end of the school year: the data show unequivocally our students have not internalized the learning outcomes for use in other contexts.

The evolution of this course is itself a design thinking process. As we reflected upon this first iteration, we concluded one characteristic of our learners is their almost complete lack of exposure to the real world and predisposition toward a pragmatic worldview. Students cared about whether the class would help in their majors, provide a skill to improve the odds of obtaining a job, create a credential to facilitate admission into graduate school, and the effect of the class grade on their Grade Point Average (GPA). Most of our students grew up going to school, studying, doing well on standardized tests, and repeating that cycle until admission to university. They had little grasp of practical life.

As a result, we devised a different entry point into design thinking by linking the content to the student's life experience hoping to pique their curiosity and using those experiences as the starting point for a class project. Our second prototype of design thinking, therefore, highlighted the creating solutions aspect of design thinking. With this change, we hoped students would find the course more attractive and engage their creative abilities. While students expressed more interest in the course, one unintended consequence of our new approach emerged: the emphasis on solutions fed into our students' training and reinforced their tendency to look for the single correct answer—exactly the opposite of what we hoped to achieve. Though the faculty emphasized the goal of the course lay in the journey of searching for the solution through inquiry, students paid no attention. Instead, they placed maximum value on generating a solution, viewing the design thinking process through the same lens as learning the process to solving a differential equation. In their minds, the answer was what mattered.

In the final analysis, the students' inability (or unwillingness) to ask questions meant that they did not grasp the fundamental purpose of design thinking to identify a hidden core user need (problem) rather than

accepting the obvious articulated user need. For example, one team of students decided to look at the issue of insufficient lockers at the university. After two weeks of user research, surveys, and interviews, the team came to office hours with the following question: "We don't understand the point of this exercise. Isn't the solution to our problem simply adding more lockers?" It never occurred to them to look at whether demand for the lockers fluctuated, and if so, the reasons for the fluctuation. Nor did they investigate what percentage of the students used the lockers, why students used the lockers, and how they used the lockers.

Overcoming the 'Software' Obstacle: Pinning Down Our Teaching Philosophy

As we reviewed the problems we encountered,[19] especially the mismatch between our goals and the students' performance and mindset, we further revised our course design. This time we localized our core teaching philosophy. We combined experiential learning with traditional test-taking, short lectures with interactive exercises, and, most importantly, emphasized academic rigor throughout every phase of the design thinking process. We chose to deliver the course in workshop style divided equally across lectures, in-class exercises, and project time in and out of class. In this 'east meets west' approach, we allowed our students to engage with pedagogy familiar to them while slowly introducing and guiding them through the more experiential self-directed segments of the course.

We introduced academic rigor by making critical thinking a primary feature of our course. The course begins with an introduction to critical thinking as a foundation for the balance of the course. Students learn the role of assumptions (identifying and questioning); the distinction between causation and correlation; the centrality of defining terms and other basic tools of reasoning. Using this knowledge as a springboard, students learn the fundamental tools and processes of design thinking with an emphasis on identifying and reframing the problem (rather than solving the problem), identifying user needs, and grasping the concept that more than one right answer exists. Throughout, students also work on connecting critical thinking to design thinking. It took a lot of effort to lead our students

[19] Apart from debriefing and brainstorming, we also collected and analyzed students' feedback through short surveys and informal conversations with students both individually and in groups.

who are immersed in scientific issues to identify wicked problems. Students came to design thinking with two critical preconceived misunderstandings: the first was that technology and solutions were synonymous (rather than conceiving of technology as a tool to achieve a solution); the second was a firm belief in the existence of a singular correct solution.

Traditional design thinking processes yield valuable insight during the user research phase, both in terms of identifying a core need, as well as potential solutions. These courses begin with the premise of human-centeredness: find the human side of the equation and potential solutions present themselves. The bias toward technology meant our students had no context for understanding human-centered design or empathy. We quickly realized we could not simply mention the concept empathy to students with the hope that they would make the connection to users' needs. We thus framed identifying user needs as an exercise in critical thinking, as well as learning how to apply basic social science research methodologies.

Finally, we made teamwork the core of the students' experiential journeys. Our students have very little experience working together in teams. All exercises required teamwork and assessments made primarily based on teamwork outcomes. They often expressed frustration with teamwork, insisting they could work more efficiently as individuals. More critically, our student teams tended to focus on attaining consensus at the very outset of a process. We call this a tendency to collaborate for consensus rather than for innovation. We wanted, however, to challenge them to collaborate as teams and hold each other accountable, which mirrors how they are expected to work in the real world. Thus, for example, we introduced the concept of teams by challenging the students to define team, teamwork, the value of a team, and eventually requiring them to create their own team norms.

An Adapted Course Structure

Design thinking traditionally consists of five modules: Empathize, Define, Ideate, Prototype, and Test. The five stages do not require linear or sequential execution. They do, however, require iteration, repetition, and most of all, enough time. Considering our course takes place over 8 to 16 sessions during a 4- or 8-week term, we restructured to coincide more closely with our learning objectives: Define, Reframe, Ideate. We tell the students this course requires them to identify an issue and verify assumptions through an

understanding of human behavior. The students are mainly assessed by a final project requiring them to articulate their journey to finding an appropriate issue; their proposed solution only counts for one-fourth of the final presentation grade. We teach in both English and Chinese (all course materials are in English) and ask the students to try and present in English but do not require it.

This new three-stage framework has multiple benefits. First, it emphasizes the role of critical thinking in design thinking. Second, students experience first-hand the importance of verifying assumptions and the consequences of false assumptions. Third, by identifying a problem in relation to real-world users, students can establish a link between critical thinking, human behavior, and human-centeredness.

In the Define segment, we require the students to connect their newly learned critical thinking skills with design thinking. The students analyze the meaning of teamwork, what it means to work in teams, and select a problem, as a team, to solve. For example, we use the 'Desert Island Challenge'[20], which poses an unusual hypothetical situation, to give them experience working as a team.[21]

Define essentially encompasses 'sensing,' a traditional design thinking process, where students collect data through field research and desktop (primary) research. We teach them techniques such as mind-mapping to enhance brainstorming sessions, followed by desktop research and field research (mainly using surveys and interviews). Students must use their critical thinking skills throughout. In our revised syllabus, we reiterated the essential role of critical thinking when doing primary research. For example, when introducing research, we asked students to evaluate the nature and source of materials for reliability, identify the author's underlying assumptions, and strength of the arguments made. In terms of field research, we briefly introduce techniques of designing survey questions and open-ended interview questions. We plan to make further adjustment to provide students more guidance in this area.

[20] See Appendix B.

[21] A few teams surprised us by stating their goal to enjoy fully the last moments of their life, leading them to choose rum and cigarettes which they had never tried before. Another team decided their odds of survival were low and they hoped to express their love and care to their family, so they selected the ballpoint pen, magazine, and rum bottle to make a drift bottle with messages to family members.

Reframing is a concept borrowed from THINK[22] with the goal of "overturn[ing] conventional wisdom to discover new possibilities."[23] We task our students with a simpler objective: analyze their data and apply critical thinking to work out which initial assumptions they have verified and which they have disproven and consider how those assumptions change the nature of the problem they have chosen to solve. In essence, we ask them to reframe their initial problem through critical thinking and sensing. We teach them to use the classic design thinking formulation of 'How Might We …' which allows them to connect the problem and objective to a specific group of users. In fact, students must constantly engage in 'reframing' through the duration of class.

Outcomes and Lessons Learned

Outcomes

Happily for us, we saw a dramatic increase in students' interest in the course. Originally, more than 80% indicated zero interest in the course. As a measure of our progress, that number slipped below 20% in the Spring Semester offering early this year. Another indicator is the number of students who choose to take our upper-level innovation courses that is built on the skills gained during design thinking.[24] A surprisingly large number of students expressed interest in enrolling in our Minor in Innovation and Entrepreneurship, and most exciting, some students expressed their eagerness to work further on the project they developed during design thinking course. Overall, most students started to exhibit qualities of critical thinking by the end of the course. Through identifying assumptions and real-world research, they came to appreciate the value of technology as simply one of many tools to solve social issues. Design thinking aims to teach two primary lessons—human-centeredness and rapid iteration. In China, with the focus on rapid change, we realized our students needed to learn to slow dow.

[22] THNK is an institution based in Amsterdam, dedicated to training creative leaders with the goal of solving some of the world's biggest problems.

[23] THNK, 'About Us,' last updated December 21, 2017, https://www.thnk.org/about-us/. THNK is a creative leadership academy based on Amsterda*m* that "develop*[s]* and support*[s]* creative leaders around the world to find new solutions and opportunities to address the world's most persistent social challenges."

[24] In our school, we provide advanced-level selective courses in relation to entrepreneurship and innovation and completion of design thinking is a prerequisite of all these courses. Students can also choose to Minor in Innovation and Entrepreneurship.

Scaling

One other feature of the Chinese context is the scale. In most places, design thinking courses are limited to 30 or 40 students per course with multiple instructors. At ShanghaiTech, we must teach 300 students per year with a teaching staff of 4. Given that it is an obligatory course for freshmen, and STEM students have a very heavy course load, most students prefer to choose design thinking during the 4-week summer term. As a result, we often have a big class of around 150 students in summer, which on its face seems to minimize the opportunity for interactivity. We had no choice, however, but to reorganize the course—more short lectures, more mandatory office hours, and restructuring of in-class exercises. We introduced more peer-to-peer learning giving the students more access to a diverse range of ideas from their peers. We put together a group of instructors from diverse backgrounds (design, engineering, computer science, social sciences, and start-up businesses), exposing the students to multiple perspectives during the mini-lectures and brainstorming. These courses resulted in surprisingly positive outcomes.

Next Steps

We intend to continue refining our approach as we gain experience and insight into our students' needs. For example, during the 2017 summer session, we noticed our students often confused the concept of an assumption with making an assertion. Some students categorized their opinion as a singular assumption, thereby failing to understand their assertion included a number of assumptions. Critical thinking continues to be a challenge.

Similarly, students often conflate their solution with their 'how might we' questions. We realized we need to clarify the rationale for the construction of the question so that students might understand the requirement for specificity of target user, broadness of a problem while providing direction for potential solutions. Finally, our students still struggle with creating original solutions. For instance, not surprisingly, students tend toward smartphone apps as solutions.[25] We hope to find more examples and case studies of low-tech (or no-tech) solutions to offer as inspiration.

[25] See Appendix C for examples of student projects.

Most importantly, this course cannot have the impact it has in places such as Stanford or MIT as an isolated innovation. At present, SEM's tenure-track faculty participate by teaching the Critical Thinking Module, as well as offering advice for projects. SEM plans to provide training to faculty from other schools on design thinking in the hopes that eventually, faculty from all four schools will participate in delivering design thinking to ShanghaiTech's students.

Great potential also exists in terms of connecting design thinking directly to the students' other courses. For example, we have spoken with the School of Information Sciences (SISTI) about allowing SISTI students to connect the design thinking final project to a required project in the mandatory Introduction to Information Science course. As we gain experience, we intend to expand these types of connections.

We are also trying to link design thinking course to other activities at the university, such as the freshman social responsibility project (a mandatory course worth one credit). In the spirit of design thinking, we need to deepen our understanding of our students. What are they eager to know? Which topics are they interested and why? What kind of support do they need? The greatest challenge in delivering innovation education is to turn young learners' confusion into curiosity. They are not unwilling to learn, but it is incumbent upon us to find the appropriate starting point to facilitate the learning process.[26]

A Metaphor for the Future of Innovation in China

China's success over the last 30 years has been a constant process of learning from the West and scaling. Large infrastructure and urban development projects relied on a combination of massive government investment, Western know-how, training local teams, and a large labor force. Over time, as local engineering talent gained experience, China began to set the standard in areas such as high-speed rail travel. More recently, China's home-grown innovative companies, such as cTrip, Alibaba, DJI, and Tencent, have changed the paradigm for innovation by relying on the 'take and adapt' model: they have succeeded by taking Western business

[26] This summer, for example, we introduced a new course on designing computer games. The course focused on teaching the students to understand what makes a good game, the creation of a story, and the interaction between gamer and game designer. Many of these skills share an origin with design thinking.

models and adapting those to the needs of the local Chinese market. As China's requirements move from building things to building people, ecosystems, and cultures, this newer model has taken hold at the highest level.

China's leadership has expressed a desire to find a unique Chinese model in everything from financial systems to economic and political models, as well as education.[27] Our experience in education offers some hints as to how this process unfolds and its implications for what innovation might look like here in China. Moreover, the challenges we have met in China offer valuable lessons to the rest of the world in terms of promoting and sustaining innovation education.

Capital Investment Model and Scaling

When it comes to innovation education, China has taken concrete steps in the form of capital investments and policy changes to jumpstart innovation education at a massive scale. The country has committed to massive investments in higher education (and the research that supports these institutions) just as many more developed Western countries are moving to do the contrary. Many have written articles about the increased funding for science research, labs, and luring prominent academics (as well as recent graduates from PhD programs) back to China from overseas positions. While monetary investment is not a panacea, its existence certainly makes preparation for the 4IR more feasible.

Educational institutions endowed with extra funding for innovation have, in turn, initiated panoply of new programs, projects, and classes, with the only requirement that the endeavor include the words innovation and entrepreneurship. The quality of the programs and courses vary widely as does the quality of the faculty. If Western counterparts examine the course content and delivery, it will often look unrecognizable. The system sets numeric metrics for success, for example how many incubators, classes, students, and fab labs are present. None of the metrics explicitly address the quality of any individual initiative. This leads to many false starts and wasted resources.

On the other hand, China does not lack for capital and has the law of numbers on its side. A 1% success rate in China, on an absolute numeric basis, dwarfs numbers elsewhere (with the exception of countries like India and

[27] Bruce Fuller, "A Shifting Education Model in China," *The Atlantic*, December 14, 2015, https://www.theatlantic.com/education/archive/2015/12/china-education-system/420234/.

Brazil). With a population of 1.3 billion, having impact means doing things at exponentially larger scale than elsewhere. This type of scale allows for large numbers of experiments and more data points for success. The downside, however, is that a defective outcome in an experiment can often affect a large population. Innovation itself is about trying and often gaining surprisingly good results after multiple efforts. In this sense, China epitomizes at least one type of mindset required for the future: willingness to experiment, ability to incorporate learnings rapidly, and operating in uncertainty.

In short, the Chinese approach favors massive experimentation, wide beta in terms of results, resulting in a low rate of return on its investment. This approach is difficult to replicate in countries such as the United States with its wrangling over taxpayer dollars. Countries in Africa, elsewhere in Asia, and South America, on the other hand, could consider adopting a similar approach (although one must consider the variations in government control).

Isolated Efforts Do Not Equal Ecosystem Change

With three years' teaching experience, we have adjusted our course accordingly and have reached a clearer understanding of what we can do to push our students to think more critically and creatively. We feel confident in our short-term impact based on feedback, observed outcomes, and student involvement at SEM. However, we still face several challenges as well as some questions about longer-term impact. At the risk of stating the obvious, simply introducing design thinking as a compulsory course in universities cannot fundamentally help students to think more creatively. The changes that design thinking alone can bring are small and transient. We are aware that students need more support to help them through the transition from an exam-oriented didactic educational setting to an inquiry-based experiential learning environment. Our tech-savvy students possess the fundamental abilities to learn the skills and knowledge to thrive in the 4IR. But in order to bring fundamental change in support of innovation, understanding what and how is far from sufficient. They need to be able to think about and figure out why, why not, so what, and what else.

Our biggest challenge is that design thinking now stands alone as the singular mandatory course taught socratically in combination with experiential learning.[28] The macro-environment has not changed commensu-

[28] Experiential courses can be said to constitute standard fare in science and engineering curricula: computer coding classes and lab work, for example, constitute experiential courses.

rately. No connections exist between design thinking and more traditional courses taught by tenured faculty, whether in SEM or the other schools. While students can easily access activities such as hackathons, innovation competitions, and seminars and conferences on the theme of entrepreneurship, they do not have sustained guidance and mentorship to take forward what they have learned from design thinking. That is to say, our efforts to 'stimulate critical thinking and creativity' are quickly diluted during the course of their daily study and lab work.[29]

On a macro basis, nurturing innovation at a national level requires dedication from multiple domains and demands more input in 'software' than 'hardware.' Universities alone (let alone a handful of faculty) cannot make any sustained systemic changes. Apart from increasing industrial partnerships, a more coherent and interconnected network must be formed. For instance, wholesale curricular re-design from the elementary level to undergraduate (and even post-graduate level) must occur. Teachers must adapt teaching styles and change course design. In parallel, universities, communities, industry, government and non-government organizations must share a mission to form deeper meaningful partnerships to support innovation-driven learning settings, workplaces, and robust environments.

Design Thinking Is Really About Thinking

We have expressed the need for contextualizing the structure and curriculum of design thinking. At ShanghaiTech, this included factors such as students' learning habits, STEM majors, and life experiences (or lack thereof). It turns out that planting the innovation and entrepreneurship seed meant challenging students' thinking modalities and inspiring them to believe they could make a difference in society's future well-being by creating solutions to wicked problems (particularly social issues in China). Therefore, we have placed critical thinking at the core of our course. Critical thinking is not simply an isolated section at the beginning of the course. We constantly refer back to critical thinking not only in the formal design thinking portions of the course, but also to prompt student reflection on topics such as academic integrity, ethical implications of bioengineering, and social responsibility.

[29] SEM currently does not offer any majors or degree-granting programs.

We have witnessed an improvement in our students' critical thinking abilities, and a few students have told us that they consciously apply what they learned to their other studies and projects. Reflecting back on our journey of teaching and adapting the design thinking course, we feel confident the course acts as a gateway for students to approach problems with a critical mind while creating solutions by making unexpected connections. Design thinking is far from simply design for us. It is an intellectual trigger, urging learners to unlearn and relearn in response to the complexity of real-world issues.

The effort in China is a mirror for educational reform efforts around the world. The ultimate goal of innovation education (or any education) is really about stimulating students to think critically in uncertain environments and take action to create a better world. No singular course, curriculum, or technology can substitute for the hard thinking that must go into teaching our students how to think and behave in this way.[30]

Challenge of Cultural Change

In our view, simply allowing us to teach design thinking to STEM students at a new Chinese university signals a certain level of openness within the system, particularly with regard to the concept of critical thinking. Knowing that 'how' a course is taught weighs more than 'what' is taught, we do not underestimate the challenge of impacting deeper change. China's long history of exam-oriented education (as well as a corresponding school system and evaluation mode) poses formidable obstacles. Equally challenging in China is finding qualified instructors and interested tenured/tenure-track faculty.

At its root, however, critical thinking entails questioning authority, and a certain degree of freedom of thought. In the West, we equate these things with academic freedom and democracy, which in our view sets the foundation for creative thought and truly disruptive innovation. One might argue that most of China's innovation to date comes simply from the normal learning process that happens between developed and developing nations. While we agree with this observation, we believe it also undervalues China's success in growing its economy. At the same time, China is yet to produce what some might consider a 'true disruptor'—

[30] At some point, countries will also need to face the challenge of how we measure innovation education and innovation itself.

almost all of its current innovation can be categorized as business model innovation (or more uncharitably, copying and adapting), variations on existing products, or incremental innovation.

From our perspective, this leads to (at least) two critical open questions. *Can incremental innovation lead to genuine disruptive innovation? Can the requisite critical thinking necessary for innovation occur without the attendant levels of freedom of thought?* We believe China is searching for the answers to those questions. Unquestionably, China's leadership understands the dilemma they face in encouraging innovation: balancing the need for innovation and economic growth that requires loosening of control with maintaining its current political structure and control. This balancing act is at the crux of their desire to find a Chinese model of innovation. Can China take the lead in artificial intelligence, not simply in research, but in commercial application in the current intellectual environment? Do the right ingredients exist in Chinese universities? We do not have a clear answer to this question. Significant governance issues make it difficult to see a path forward. The university environment of fertile intellectual discussion, creation of knowledge, and disagreement that we recognize in Europe, Australia, and the United States does not exist quite yet in China. Yet perhaps enough of the requisite pieces will fall into place to generate some version that is true to the Silicon Valley model of "just good enough".

Conclusion

China faces a great many challenges domestically magnified by the oncoming 4IR. Finding a model to innovate is core to China's success. Successfully finding a model to innovate will be a good barometer for measuring China's efforts to find its own models in other domains. Will these efforts yield results that the nation can take pride in? Will China be able to cultivate smart talents to create smart systems for the human world at the age of 4IR? For China, its determination, its humility to learn from better examples, its long tradition of diligence and perseverance are its greatest advantages for driving innovation forward. It is still too early to say that a Chinese model of innovation has begun to emerge.

Pessimists about China predict a hard crash. Optimists predict the future belongs to China. We classify ourselves as realistic optimists: not sanguine about the challenges China faces, but not willing to bet against a country which has achieved an economic miracle never before witnessed

in human history. The world's future depends on a prosperous and peaceful China. With the right guidance, with human-centeredness at the core and where ethical and moral issues associated with the 4IR are carefully considered, as educators, we believe in our students and their potential to shape the future.

Appendix A: General Education Models

In most Chinese universities, each student enters the university with a major (which they selected when they took their college entrance examination) and their courses dictated by the relevant schools.

Compulsory Courses for Freshmen

Fudan University

Fudan's Generation Education Program classifies core courses into seven categories, namely Classics Literature and History, Philosophical Wisdom and Critical Thinking, Dialogue of Civilization and Global Perspectives, Social Research and Contemporary China, Scientific Exploration and Technological Innovation, Care for Environment and Life, Art and Aesthetic Experience.

Special Programs

Peking University and Tsinghua University

Beijing University founded the Yuanpei College in 2007 and each year the college carefully selects and enrolls a small number of undergraduate students. The students take general lessons at the college in their first year and they then select their major and take major courses in the faculties. A similar program was introduced at Tsinghua University in 2014 when the Xinya College was established.

Appendix B: The Desert Island Challenge

You are a group of strangers who have been cruising around the Indonesian Sea, enjoying all the luxuries that a top-class cruise liner has to offer.

Last night, a bad storm left your ship in pieces and your group is the only remaining survivor.

Table 5.1 List of items to choose from for the desert island challenge

Body-warming bag (foil)	*Set of 4 flares*	*Tin of beans*	*Pack of cigarettes*
Torch with batteries	Whistle	Box of matches	Set of keys
Large rope	Blunt knife	Mirror	Bottle of rum
Set of 3 small fishing hooks	500 ml bottle of water	Sleeping bag	Magazine
Basic first aid kit	Ballpoint pen	Mobile phone (not a satellite phone)	Tin cup

You are in a small lifeboat with five other people. There is very little room and you are only just managing to keep the water out. You have some things in a small rucksack that will help you to survive once you reach the desert island that you can see on the horizon.

However, you cannot take them all with you. You can carry five of the items from the rucksack and you have 25 minutes to decide (which includes transition time to your breakout area and back).

Your team must then explain your choices in 3 minutes to convince me that you made the right choice. I want to know which items you chose and the rationale for your team's choices.

Appendix C: Examples of Students' Projects

During the most recent summer term, students worked on projects with the grand theme of 'making old people happy.' We list two examples from this term illustrating the students' realization that simple design (rather than application of technologies such as VR) often provides superior solutions.

Eat Better

Insight: Most old people had dental problems and even those who wore dentures found it difficult to eat healthy yet hard food.

How Might We Question: How Might We help elders wearing dentures eat hard food?

Solution: Meat hammer and creative food knife.

Note: The group started with a number of common issues facing the elderly: Malnutrition; Aspirations; Social Contact; Empty-nester. At the

ideation stage, they came up with solutions which they subsequently divided into four broad categories:

1. new tools that change the texture of food;
2. new ways of processing food;
3. new methods to improve existing dentures which fit better;
4. ways of warning them not to eat the type of food that might hurt their teeth.

They measured their solutions on the feasibility and impact axis and selected four products. The students even created a visual demo and did a small-scale user test, after which they gained feedback and identified their final solution.

Towel Wringing Gadget

Insight: Old people are not willing to use high-tech products or do not care about high-tech problems. Arthritis, however, can be a big problem that affects old people's happiness in their daily life.

How Might We Question: How might we design a product to help senior citizens with arthritis problems (who are not willing to accept technology products) overcome inconvenience caused by arthritis?

Solution: Towel Wringing Gadget

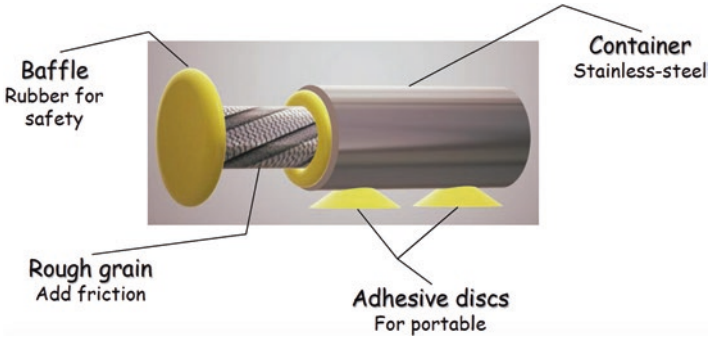

Fig. 5.1 Towel wringing gadget

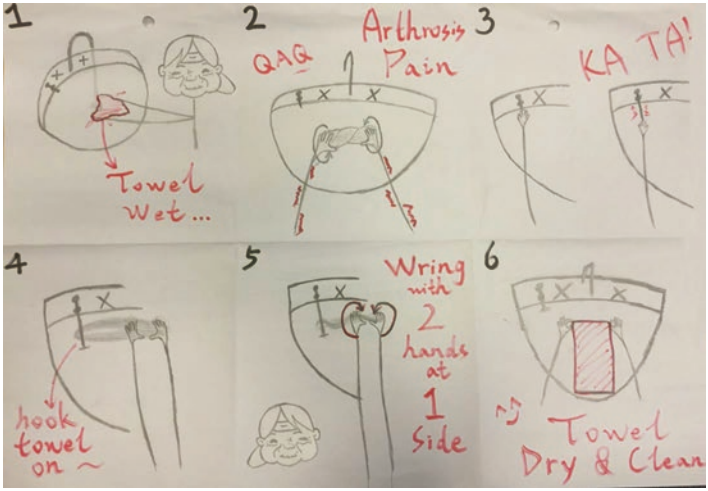

Fig. 5.2 Towel wringing gadget drawing

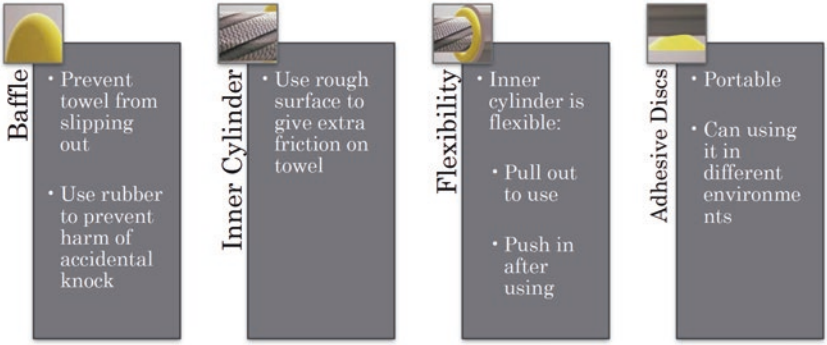

Fig. 5.3 Operation of towel wringing gadget

Here are two other examples from earlier terms when students had the total freedom to work on problems that they themselves identified. While the solutions of the following two projects do not win high marks in terms of their originality and creativity, they exemplify that students spent much effort and time in locating a wicked problem that they care.

Dress and Appearance of University Students

Problem: University students' clothing is closely linked with their self-esteem and confidence (and thus affect their job-hunting).

Insight: Guys do not have enough motivation nor knowledge when it comes to improving their appearances. They do not have any interactive and customized tools that offer them feedback about their clothes.

How Might We Question: How might we create effective ambience for male university students to discuss their clothes (with an aim to stimulate them to improve their appearance through helping them to better choose their outfits)?

Solution: A social application that provides a community where users can get rates and feedback on their clothes as well as professional advice and recommendations.

Food Waste Reduction in Restaurants

Problem: Food waste is a common problem and the cost for processing food waste is extremely high.

Insight: The situation of food waste in hotpot restaurants is more severe as it is not easy to take away unconsumed food.

How Might We Question: How might we reduce food waste in hotpot restaurants with lower cost?

Solution: A specially designed menu that matches customers' diverse needs (dietary and emotional) coupled with detachable tableware.

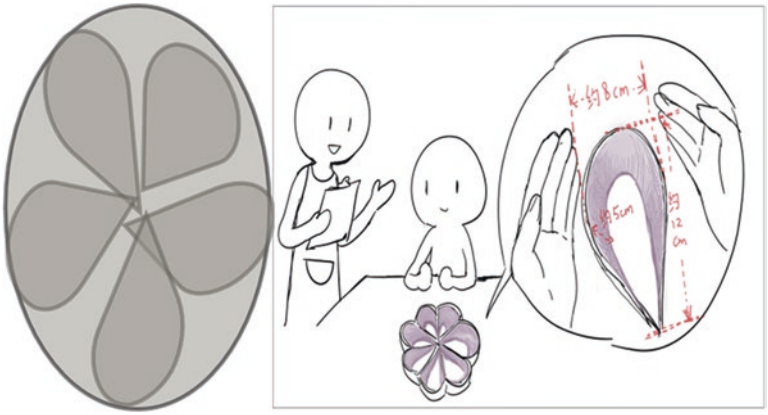

Fig. 5.4 Example of detachable tableware

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