Urban sustainability education: Challenges and pedagogical experiments

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ABSTRACT
The twenty-first century will witness massive urban expansion and growth of the urban population, which has global implications for future pathways of sustainable development. Addressing new and heightened demands on the environment, energy resources, and infrastructure will require holistic comprehension and actionable approaches to the city as the nexus of environmental context, built infrastructure, and human communities through interdisciplinary collaboration. Yet urban sustainability is a vague and elusive concept that fails to inspire actionable and effective actions; to teach urban sustainability is an even more daunting task, which requires drastic changes to conventional pedagogical structures and processes. This paper describes the experiences of a university course to prepare students with diverse academic backgrounds to develop the skills to understand and address challenges in urban sustainability. The course is jointly offered by three academic programs at Tsinghua University and Stanford University and uses Beijing and the Bay Area as two case studies. Experimenting with a combination of teaching principles that are critical to cultivate young professionals, this course offers a unique cross-cultural and interdisciplinary educational experience that allows students to explore urban sustainability topics ranging from air quality to urban mobility, heritage buildings, and energy conservation in consultation with local experts, scholars, and non-governmental organizations. Lessons detailed in this paper can benefit the development of similar courses around the world to foster higher education in urban sustainability.

1. Introduction

Cities cover three percent of the world's land, yet are responsible for up to eighty percent of global greenhouse gas emissions and seventy-five percent of natural resource consumption (United Nations Environment Programme). Urban areas affect air and water quality, alter resource consumption patterns, and create greater burdens on the natural environment, energy resources, and infrastructure. Developing and developed countries alike will test these limits in the 21st-century. While developed economies such as the United States continue to grapple with auto-centric, fossil-fuel intensive patterns of development (Calthorpe, 2010; Kunstler, 1994), the growth of cities in emerging economies such as China, where rapid urbanization has already occurred and continues at an unprecedented rate, has resulted in severe environmental degradation (Economy, 2011; Edmonds, 2012; Smil, 1985). Looking ahead, China is expected to add 300 million residents to its cities by 2050, approximately the current population of the United States (United Nations, 2014), raising questions about what can be done to reverse the present course of detrimental development.

Addressing these challenges requires understanding the city as the nexus of environmental context, built infrastructure, and human communities, which in turn requires collaboration among scholars and practitioners from diverse disciplines. Given the trend of globalization, cities across the world are becoming increasingly connected, and their respective paths and experiences in addressing urban challenges are valuable to each other (Hsu & Chan, 2014).

Motivated by these needs, the Program on Urban Studies at Stanford University (referred to as Stanford hereafter) in the United States invited and worked with the Department of Construction Management and the Department of Information Art and Design at Tsinghua University (referred to as Tsinghua hereafter) in China to jointly offer a project-based, experiential learning course focused on comparative urban sustainability to students from both institutions. The course, titled Sustainable Urbanization in a Comparative International Perspective at Tsinghua and International Urbanization Seminar at Stanford, is one of the courses offered through the Human Cities Initiative at Stanford whose vision is to foster human-centered technological, policy, and design strategies to address urbanization challenges (Human Cities...
Initiative, 2017). This course offers students a comparative approach to the study of sustainable cities as cities are increasingly understood in an international context. Students are encouraged to identify distinct challenges of urbanization at different stages of development, explore historical and contemporary urbanization trends in China and the United States, and investigate tradeoffs and choices regarding land use, energy, and water resources, and confront the challenge of balancing economic vitality, environmental quality, cultural heritage, and social equity (Hsu & Chan, 2014). By reporting the authors’ experience in teaching this course during the academic years 2015-17, this paper aims to examine the effectiveness of educating students about urban sustainability based on a number of fundamental teaching principles that are experimented with in this course. This paper also aims to reflect on various lessons learned, advocate new approaches to evaluating student learning outcomes by employing a holistic framework of urban sustainability, and hence address the research gap of major challenges that require further pedagogical innovation. It is expected that the findings will contribute to the theoretical framework and development of similar courses in other institutions around the world, consequently the improvement of higher education in urban sustainability, and ultimately the cultivation of young academics and professionals who will make real and profound impact on urban sustainability in the future.

2. Principles for teaching urban sustainability

Though touted in policy documents and academic papers, the term “urban sustainability” remains a vague and elusive concept that fails to inspire actionable and effective actions (Jabareen, 2008; Keirstead & Leach, 2008). To introduce and teach this topic to university students who often lack formal training or prior work experience is an even more daunting task, and therefore requires drastic changes to conventional pedagogical structures and processes.

The restructuring of such curriculum would require the following: different subjects and disciplines need to be integrated; students should learn to adapt and collaborate with different mindsets; materials discussed in the class should be presented within global, regional and local contexts; and students should learn to work with different stakeholders who may have diverse technical as well as cultural backgrounds, and mutual or conflicting interests. As cities should be understood as the nexus of environmental context, built infrastructure and, most importantly, human communities, students need to extensively interact with communities in order to empathize, critique and solve the emerging challenges in which cities and their urban dwellers face (Hsu & Chan, 2014). Urban challenges theoretically described in the class need to be connected to real-world problems, and students should engage in experiential learning that is carried out with self-regulated processes.

These criteria have led to the development of several teaching principles, which have been integrated and adopted in this course as explained below. The authors implemented these pedagogical strategies to ensure that students were exposed to urban sustainability within an interdisciplinary and cross-cultural setting through a project-based and self-regulated process that infuses human-centered design.

2.1. Interdisciplinarity

Urban challenges are rooted in complex systems, the understanding of which requires a holistic view that merges knowledge from multiple domains. It is not possible for a single discipline to capture the complex nature of sustainability (Steiner & Posch, 2006), let alone its implications in urban development. In practice, the effective management of cities has been a multi-disciplinary endeavor that requires fluency in multiple areas. The academy and its curricular offerings are adjusting to this reality. While it is not likely to educate students to become experts in all areas, it is far more critical to prepare them to work with experts from different areas as a team.

This course is envisioned to provide students with an interdisciplinary educational experience. The benefits of teaching engineering with design (Gillie, Moore, Caron, & Mansfield-Williams, 2015), design with science (Crinall & Henry, 2008), and design, engineering with social sciences have been documented (Norman, 2010), yet, fewer pedagogical efforts have bridged the domains of urban studies, engineering, and design in the query of solutions to urban challenges.

As such, the authors developed this course to blend students from urban studies, engineering, and design in interdisciplinary and multinational teams. Student teams were guided to examine urban sustainability challenges from social sciences perspectives, analyze the problems and develop and test their solutions using engineering methods, and develop prototypes and exhibits to visualize and disseminate their findings using human-centered design thinking. This collaborative structure has been continuously adapted and improved throughout the process, allowing students from various academic disciplines to contribute to their projects, while learning and benefiting from perspectives that other students bring to the team.

2.2. Cross-cultural collaboration

It is important for students to understand both a familiar and unfamiliar context such that they can make an adequate assessment of cities without simply believing that one set of conditions is natural or universal, yet also recognize the key similarities that underlie urban challenges. Unfortunately, the knowledge and skill sets taught in traditional university classes do not equip students with these skills. Students commonly lack the required cross-cultural social, technical and managerial skills (Soibelman et al., 2011). They may be unfamiliar with the history, social norms, lifestyle and policies of other countries. Their exposure to interpersonal communication, team collaboration, project management, and leadership are mostly domestic in nature and inadequate for international practice (Doerry, Doerry, & Bero, 2003; Fruchter, 2001; Kalay, 2001; Steele & Murray, 2006). These deficiencies have attracted considerable attention within universities in recent years and sparked various efforts in the internationalization of curricula in response (Altbach & Knight, 2007; Chead, Chen, & Ting, 2005; Last, Hause, Daniels, & Woodroffe, 2002; Littrell & Salas, 2005; Peña-Mora & Vadhavkar, 2009; Steele & Murray, 2000). This latest trend is inspiring, as students are provided with increasing exposure to educational experiences in international contexts and more opportunities to interact with and learn from their peers from different cultures. However, significant gaps still remain where higher education in urban sustainability is concerned. First, there is no published pedagogical efforts to the best knowledge of the authors that aim to teach urban sustainability by fostering cross-cultural collaboration. The rapid urbanization of the twentieth-first century requires new approaches to urban sustainability. Whether and how cross-cultural collaboration can address these challenges and how students can be properly trained for such collaboration, still requires investigation. Second, prior efforts in the internationalization of curricula were made within a single discipline, such as engineering, design, and social sciences, whereas cities constitute complex engineered socio-technical systems, the probe of which requires a blending of approaches and knowledge across various disciplines and collaboration between people from distinct backgrounds. The management of cities requires interdisciplinary and cross-cultural collaboration, which is de facto in practice but has rarely been investigated in the higher education of urban sustainability, an important subject that deserves further examination.

In response to these needs, the authors emphasized cross-cultural principles in teaching the course and aim to expose students to a cross-cultural learning environment in several ways. Students learned about urbanization in China and the U.S. using Beijing and the Bay Area as case studies in weekly lectures and discussions. In multi-national teams, they exchanged thoughts and collaborated on assignments and term
projects. They also traveled to the specific sites where they physically experienced urban life outside of their familiar contexts and learn through interaction with local communities. By integrating a cross-cultural educational experience with urban sustainability settings, students were encouraged to cultivate their consciousness and ability to work with people across different cultures to address emerging sustainability challenges in cities worldwide.

2.3. Project-based learning

Project-based learning (PBL) is an active student-centered form of instruction which is characterized by students’ autonomy, constructive investigations, goal-setting, collaboration, communication and reflection within real-world practices (Kokotsaki, Menzies, & Wiggins, 2016). Project-based learning is a popular methodology in developing students’ fundamental, critical and research skills (Basilotta Gomez-Pablos, Martin, & Garcia-Valcarcel Munoz-Repiso, 2017), and has been adopted in a wide range of domains at various stages of schooling (Becerik-Gerber, Ku, & Jazizadeh, 2012; Han, Capraro, & Capraro, 2016; Mahgoub, 2015). Yet, how to adapt the form of project-based learning to the particular needs of higher education of urban sustainability remains to be investigated.

To address this gap, two attempts were made. First, students were guided to follow a service learning approach, defined as a structured learning experience that combines community service with academic coursework and reflection, in their project development. Service learning can take multiple forms, ranging from direct service (e.g., working face-to-face with impacted populations), research-based (gathering and presenting information), to advocacy-based (educating others about a topic to create awareness and action), which are all experimented in this course (Hsu & Chan, 2014; Stanton, Giles, & Cruz, 1999). Students were required to reflect throughout the course on their service learning experiences and gains, which became a critical outcome of the project that is evaluated by the faculty. Second, the course emphasized the process as well as the final deliverable; this was embodied in the way that student projects were evaluated and also by emphasizing the appropriate use of process, or lack of it, in real-life urban management challenges.

2.4. Self-regulated learning

Self-regulated learning means that learners are meta-cognitively, motivationally, and behaviorally active participants in their own learning process during which they self-generate thoughts, feelings, and actions to attain their learning goals (Steiner & Posch, 2006; Zimmerman, 2001). They therefore find themselves in a position where they are forced to recognize the consequences of their own actions and may no longer attribute success or failure to forces beyond their control. In this way, they view themselves as owners of their behavior (McCombs, 2001). This concept of self-regulated learning can be viewed as socially sustainable in the sense that it empowers learners to take their learning into their own hands (Jucker, 2002).

Unlike traditional courses that adopt a top-down model where faculty are the source of information that is passively absorbed by students, a new paradigm of teaching urban sustainability requires that students be self-regulated, adopt a proactive role in the learning process, and selectively acquire and create knowledge that extends beyond the confines of any particular discipline.

Accordingly, students in this course were provided a conceptual framework and flexible structure for project definition, and consequently offered considerable autonomy to refine the scope of their term projects within these boundaries. The advice received from the teaching team on project development was mostly at the methodological rather than the operational level. Students were both the decision makers and performers with regard to project execution, solution prototyping and outcomes dissemination. In this way, the students proactively and thoroughly participated in all phases of the projects, and by doing so, they learned to empathize, analyze and synthesize, develop critical thinking competence, improve problem solving skills, and most of all, learn how to learn, which is considered by many as the fundamental goal of any education (Chan, 2017; White, 2001). All of the above were intended to nurture students’ ability to confront real-world urban issues.

2.5. Human-centered design

Emerging views of sustainable development incorporate definitions and metrics of social sustainability (Dempsey, Bramley, Power, & Brown, 2011; Magis, 2010; Vallance, Perkins, & Dixon, 2011). Cities that incorporate social sustainability invest in people-friendly infrastructure to encourage active lifestyles and vibrant public spaces (Gehl, 2013). However, a human-centered city is more than just infrastructure and the provision of physical needs—shelter, food, and livelihood; such cities empower citizens to fulfill higher-order needs for belonging, esteem, purpose, and identity (Chan & Hsu, 2015).

In order to teach and prepare students to recognize social sustainability and human-centered cities, the faculty integrated design thinking in the curriculum. Design thinking, as developed by the design firm IDEO and taught at the Stanford d.school (IDEO, 2017) and other institutions around the world (Dunne & Martin, 2006; Dym, Agogino, Eris, Frey, & Leifer, 2005), is a human-centered approach to problem solving. It involves mindsets and methods that empower inter-disciplinary teams to understand problems by making use of empathy-cultivating interviews and observations of users in the field, synthesizing insights, facilitating brainstorming and ideation, and testing ideas through prototypes (Brown, 2011; Miller, 2015). Design thinking, in this particular scenario, was intended to encourage outcomes of human-centered design in ways that advance human dignity and enable human beings to thrive and exist under diverse circumstances (Buchanan, 2001).

The course projects adopted the approach of design thinking, placing an emphasis on human needs and practicing need-finding with students. Users began their work with a focus on building empathy—undertaking different activities to understand user communities and their experiences. Teams also utilized ideation and brainstorming strategies common to design thinking to generate many ideas, some of which were identified as most promising. Later in the design process, teams built prototypes of solutions, which they then tested with the public, to gain user feedback and assess the viability of the solutions they had proposed. They then iterated on this prototype, improving its function based on the feedback from the first battery of tests, and the improved prototype was tested again with the public. By drawing on the human-centered approach offered by design thinking, and marrying it to urban questions, students were able to more effectively consider the role of human beings and impacts on human communities as part of urban sustainability.

3. Course overview

3.1. Course structure

The overall objective of this course is to help students expand their knowledge of urbanization and sustainability, acquire skills related to the field, and explore the values and ethical judgments that are tied to how communities are shaped. The course includes three major components: a studio based in Beijing, weekly joint teleconference sessions, and an expo based in Stanford. The studio is offered in the summer as an optional prerequisite to the official course. During the two-week studio, faculty and students from Stanford travel to Beijing to meet and interact with their counterparts at Tsinghua for lectures, site visits, and social events to allow the students to engage with their teammates and local community partners for their course projects. At the end of the
students, students are divided into teams across institutions and disciplines, and they select project topics to further develop during the course. After the conclusion of the studio, Stanford students return to the United States, and the class meets for joint teleconference sessions over ten weeks during the Fall semester/quarter. Stanford students are also required to participate in two 1.5 h seminar classes on campus, in addition to the joint teleconference each week. During the joint sessions, students attend lectures delivered by the faculty or invited guest experts on subjects are relevant to urban sustainability challenges and break up for team discussions on their term projects. Students are also required to work outside the class for tasks such as literature review, site visits, and observation and prototype development that are essential for their term projects. At the end of the semester/quarter, faculty and students from Tsinghua travel to Stanford to participate in the Human Cities Expo (“Expo”), which is organized by the Human Cities Initiative at Stanford and among other activities, showcases final presentations and interactive exhibits that the International Urbanization student teams develop as final deliverables for their term projects.

3.2. Assignments and term projects

Students are required to submit a series of urban laboratories where students engage in hands-on fieldwork to develop a sense of space, scale, and need-finding. In these laboratories, students capture images and video of Beijing and the Bay Area to be shared via teleconference with their peers in the United States and China, and develop prototypes for the term projects.

Written reflection is another critical component of the class, allowing students to reflect on their learning outcomes and collaboration with international students and local experts. Each reflection consists of two parts: 1) a project update, authored as a group, and 2) an individually authored reflection referring to class discussion, readings, and empirical lessons from the project.

The core component of this course is the term project. Students form multi-national teams to explore sustainability topics such as urban mobility and transport, land use and buildings, and cultural preservation, in consultation with local experts, scholars, and non-governmental organizations (NGOs). Throughout the semester, these teams of Chinese and American students meet over teleconference to plan the project, set milestones, and complete the final deliverables. At the end of the semester, students showcase their work at the Expo, an annual event organized at Stanford that brings together practitioners and scholars to discuss issues of sustainable development and urbanization with a focus on enhancing cross-cultural and cross-disciplinary collaboration.

3.3. Student communication

To ensure smooth development of their term projects, students maintain active and continuous dialogues within and between teams through various means and channels of communication. The summer studio, which includes a number of social and networking activities, provides the students with an opportunity to get acquainted with each other and strengthen team bonding. During the ten-week semester/quarter, weekly joint teleconference sessions using virtual communication play an important role. The class uses space equipped with Cisco hardware and Bluejeans software supported by industry-level cameras, embedded microphones and high-resolution splicing screens to run these online joint sessions (Fig. 1).

After all-hands presentations and announcements using the room hardware, students break up into small groups to discuss project progress and issues with their teammates, usually using laptop computers. Students are encouraged to document their communication, and summarize the outcomes of their discussions in written reflections.

A significant portion of the student communication happens in a virtual environment. It is facilitated by various information and communication technologies (ICT), which as prior studies have pointed out are critical for virtual collaboration courses (Becerik-Gerber et al., 2012; Soibelman et al., 2011). A broad range of ICT is used to support and encourage virtual collaboration and communication in and outside of the classroom. For instance, websites such as Piazza, Dropbox, Google Documents, and Qualtrics were used to facilitate discussions, homework submission, course materials distribution, project file sharing, and course evaluations. Services provided by WeChat and FaceTime supplemented e-mail in supporting virtual communication between students from Tsinghua and Stanford. Technological issues do occur that can result in loss or low quality of audio and video at times, which only further emphasizes the importance of technology to enable effective and continuous communication between the students from both sides of the Pacific.

4. Course implementation

This course was offered jointly by the three partner departments for the first time during the academic year 2015–2016. The preliminary experience and lessons learned were reported in (Li, Chan, Hsu, Fu, & Mao, 2017), and the course was revised and offered again between three departments for the second time in the academic year 2016–2017. Experiences from both course iterations are presented in this section.

4.1. First course iteration: Fall 2015

4.1.1. Student profile

Students taking this course came from different countries, disciplines and grade levels. Their nationality ranged from China, United States to Japan, India, South Korea and Singapore (Table 1). On Tsinghua side, twenty students enrolled in the course consisting of undergraduate seniors majoring in construction management and master students majoring in information art and design. Sixteen Stanford students enrolled, including undergraduate and graduate students in urban studies, civil engineering, East Asian studies, computer science, public policy, and mechanical engineering.

4.1.2. Summer studio

Prior to the beginning of the official course, two Stanford faculty, one teaching assistant and six students from Stanford traveled to Beijing and spent two weeks with their Tsinghua partners, two faculty and twenty-one students for the “Approaching the Human City” summer studio. Expert scholars and practitioners were invited to give lectures about urban sustainability to provide a foundation about urban studies and introduction of existing urban challenges. Students engaged in fieldwork to learn about the history of Beijing and collect first-hand experiences of real-life challenges, such as mobility, air quality, and culture heritage. Students were then divided into three multi-national and interdisciplinary teams. At the end of the studio, each team based on consultation with faculty and community partners, proposed a series of investigative questions to further refine the topic for the term project. In a final presentation session of the workshop, each team summarized and shared challenges observed from fieldwork and literature review on the topic for the term project and presented a research proposal for the term project, which the students would further refine and develop during their semester/quarter-long collaboration.

4.1.3. Term projects

During the fall semester/quarter, three students teams spent ten weeks working on projects they had started exploring in the summer studio. Table 2 summarizes the project files, and Fig. 2 shows a few photos of students doing fieldwork.

4.1.3.1. Project 1: Clean air campaign. The Clean Air Campaign team included 6 Tsinghua students and 5 Stanford students. They worked with community partner Clean Air Asia (CAA), a leading international NGO that promotes the mission for better air quality and healthier,
more livable cities in Asia, on a public health education campaign that aims to improve health protection of senior citizens, a particularly vulnerable group to urban air pollution in Beijing. The team conducted extensive bibliographic research to understand the health impacts of air pollution on the elderly, and conducted field research in Beijing and the Bay Area to develop and test prototypes that could be used in the campaign to educate senior citizens about the hazard of air pollution and available protective measures. Local senior citizens that interacted with the students reported increased awareness of air pollution hazards and found the tips in a brochure that the team developed helpful.

4.1.3.2. Project 2: City of cycles. The City of Cycles team included 6 Tsinghua students and 5 Stanford students. Working with China Sustainable Transportation Center, an institute dedicated to creating sustainable transportation systems and promoting a transit-oriented development, the team aimed to understand the evolution of urban mobility in Beijing and its societal impacts. The team collected a series of archival maps of the City of Beijing dating back to 1300 BC, recognized and categorized the streets with computational tools, and visualized transportation networks in an online platform. The team then studied several business and education zones of the city by surveying the current lifestyle and primary challenges of the hutong neighborhoods. They conducted traffic studies to analyze transportation ecosystems in Beijing’s historical “hutong” neighborhoods with minimum disturbance to the residents. Students started with interviews and extensive urban observations to understand the current lifestyle and primary challenges of the hutong neighborhood. They conducted traffic studies to analyze transportation ecosystems. Concluding that residents had limited energy conservation motivation due to low energy usage awareness and that traffic congestion was mainly caused by the mismanagement of road spaces, the team designed a new smart energy bill and stickers and delivered through the Stanford Institute of Design (d.school), presented opportunities to enhance public spaces that encourage inclusion and civic engagement.

4.1.3.3. Project 3: Beijing hutong neighborhoods. The Beijing Hutong Neighborhoods team included 8 Tsinghua students and 5 Stanford students. The team, working with community partner No.93 Courtyard Museum, a local community museum with a mission of cultural preservation in Beijing, aimed to improve the energy consumption patterns and transportation ecosystems in Beijing's historical “hutong” neighborhoods with minimum disturbance to the residents. Students started with interviews and extensive urban observations to understand the current lifestyle and primary challenges of the hutong neighborhood. They conducted traffic studies to analyze transportation ecosystems. Concluding that residents had limited energy conservation motivation due to low energy usage awareness and that traffic congestion was mainly caused by the mismanagement of road spaces, the team designed a new smart energy bill and stickers and a traffic caution light device and tested them in several hutong neighborhoods.

4.1.4. Human cities expo
At the end of the semester/quarter, the faculty and students from Tsinghua traveled to Stanford to participate in the Expo, which is organized by the Human Cities Initiative at Stanford (Human Cities Initiative, 2017). The Human Cities Initiative is based in the Program on Urban Studies, an undergraduate degree granting program, and aims to promote a human-centered approach to cities through interdisciplinary curriculum, thought leadership, and collaborative research.

The Expo is a daylong event taking place at Stanford that brings together interdisciplinary and multi-sector approaches to urban development that prioritizes human communities. The Expo has been organized annually and continuously since June 2014 and has attracted hundreds of participants from around the San Francisco Bay Area to international visitors. The Fall 2015 Human Cities Expo featured presentations and interactive exhibits from two interdisciplinary Human Cities classes, as well as keynote speeches from sustainability scholars and practitioners. In particular, multi-national teams from the International Urbanization Seminar showcased their final presentation and deliverables (Fig. 3). In addition, students from the Civic Dreams, Human Spaces studio, a course offered through the Stanford Institute of Design (d.school), presented opportunities to enhance public spaces that encourage inclusion and civic engagement.

4.2. Second course iteration: Fall 2016

4.2.1. Student profile
During this teaching cycle, a total of 22 and 14 students enrolled on Tsinghua side and Stanford side, respectively. Their demographic and academic background were similar in general to students in the first teaching cycle, as summarized in Table 1.

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4.2.2. Summer studio
Similar activities to the previous year were arranged for the summer studio held in Beijing, during which students from both Tsinghua and Stanford had the chance to listen to urban studies lectures, visit local communities, and interact with community partners. A major difference was the studio this year did not require students to define projects that they would continue to work during the fall. Instead, the studio focused on teaching students fieldwork skills such as urban observation, interviewing and prototyping that they would be using later on in developing their projects.
4.2.3. Term projects

During the fall, students formed teams to work on term projects, each addressing a particular urban challenge. The project profiles are summarized in Table 2. The class adopted a different approach than the previous year with regard to student team formation. Three teams were formed on each side (Tsinghua or Stanford), and in every team all members were from the same side. This allowed all students to have immediate, physical access to their project sites and closer communications among team members and between students and community partners. Meanwhile, every team was paired with one team from the other side of the Pacific, and the two teams were encouraged to learn about, comment on, and help with each other's progress during weekly joint sessions, which cultivated cross-cultural exchange and collaboration in a different way than the previous year.

On Tsinghua side, Project 1: Fusi Courtyard Rescue Plan worked with Fusi Courtyard, a community center in Beijing that provides cultural events and entertainment to local residents, to survey the residents' needs and reform the courtyard space and activities accordingly. Project 2: Participatory Urban Greenery also used Fusi courtyard as a case, but was more focused on repurposing the community and making it more social, sustainable, and greener with urban gardening approaches that the team tailored to the community's situations. Project 3: Qinglong Hutong Living Lab worked with Qinglong Hutong Community Committee, to promote cultural inheritance in a historical neighborhood in Beijing, by extending the limit of traditional culture activities with high-tech online-to-offline tools. On Stanford side, Project 4: City of Cupertino worked with the Community Development Department at the City of Cupertino to gauge the perception of its citizens about city planning and civic engagement, and improve such engagement with various strategies they developed based on extensive observations and interviews. Project 5: Menlo Spark worked with Menlo Spark, an independent nonprofit working to help Menlo Park become climate neutral by 2025. The team investigated energy assistance programs in several communities, and developed tools to funnel the residents towards the most applicable programs given their housing and income situation. Project 6: Sustainable San Mateo County worked with Sustainable San Mateo County, a civil organization whose job is to stimulate community action on economic, environmental, and social issues by providing accurate, timely, and empowering information. The team, by conducting extensive interviews and creating interactive displays, gathered various thoughts on cultural, social, economic, and environmental factors that make San Mateo County expensive and effects on sustainability.

4.2.4. Human cities expo

Similar to first course iteration, the course finished with the Expo taking place in December 2016 at Stanford University. The Fall 2016 Expo featured interactive exhibits, presentations from this course and another two Human Cities Initiative courses, the International Urbanization Seminar, UN Habitat III: Bridging Cities and Nations to Tackle
Urban Development, and Defining Smart Cities, and keynotes from sustainability practitioners and researchers. Compared to prior years, the 2016 expo saw the largest student participation with over a hundred students presenting on the main stage and creating interactive exhibits. In addition to local participation from the Bay Area, twenty students and two faculty members from Tsinghua traveled from Beijing to Stanford to participate in the expo, the largest Tsinghua cohort to do so since the collaboration was launched.

5. Lessons learned

5.1. Teaching outcomes

The authors used the four pillars of sustainability to assess whether students were able to adopt a holistic approach and framework of sustainability. Since the term “sustainable development” was first defined by World Commission on Environment and Development (1987), the literature on sustainability has recognized the need to expand the definition to include economic and social concerns (Elkington, 1998). Along these lines, Hawkes (2001) was among the first to coin the “four pillars of sustainability” as the following: (1) Cultural vitality: well-being, creativity, diversity, and innovation; (2) Social equity: justice, engagement, cohesion, welfare; (3) Environmental responsibility: ecological balance; and (4) Economic viability: material prosperity. This model was later refined by the Stanford Human Cities Initiative with a specific focus on heritage and protection of diverse human communities, thereby emphasizing the pillars of economic vitality, environmental protection, social equity, and cultural continuity.

In both teaching cycles, students submitted written reflections that summarized their experiences, thoughts, and learnings. These written reflections were reviewed by the faculty to qualitatively assess the teaching outcomes.

In addition, a structured questionnaire was distributed during the second course iteration to assess students’ self-reporting of learning outcomes in a quantitative fashion. The questionnaire used five-point Likert-scale questions to assess students’ level of knowledge about urban sustainability, skills in addressing urban problems, and comfort level of and competence in working with people from different disciplines and cultures. The questions did not directly ask the students about their gains from the class in order to avoid any bias. Instead, the questionnaire was distributed online via the class at three times: at the beginning of the course, between the end of the summer studio and beginning of the weekly sessions, and finally at the end of the course. The three sets of responses were compared and analyzed using descriptive statistics and one-tailed t-tests, to assess the improvements the students achieved throughout the entire process. A total of fifteen valid responses were collected. The respondents were mostly senior year students, including eleven male students and five female students from China, the United States, Germany and Vietnam. The results are depicted in Fig. 4.

According to the questionnaire results, students’ self-assessment of general knowledge of urban sustainability significantly increased during the studio (meaning ratings from 2.5 to 3.6, t = 4.026, p = 0.001) and was further improved slightly during the term project and expo (meaning ratings from 3.6 to 3.8, t = 1.468, p = 0.082). Their self-assessment of the specific aspects of urban sustainability defined as the pillars of economic vitality, environmental quality, cultural heritage, and social equity, also improved over the entire course (t = 2.578, 3.523, 3.119, 5.735, p = 0.011, 0.002, 0.004, 0.000, respectively). A number of students said the most valuable things they found in the course were the concept of sustainability and different case studies in both USA and China. One student wrote in the reflections that “From interviewing people, social inequality is the most prominent piece of information I found. It is such a pressing problem, and as the social gap widens, people are increasing fearful for their well-being and economic stability, while they feel as there is nothing communities can do to stop it”. Another student wrote that “I learned most in the lecture classes and from the labs how to assess cultural frameworks rooted in their urban layouts. I also learned how it has been increasing difficult to cater to both cultural continuity while attempting to rebuild urban areas in a sustainable manner without running into problems of gentrification and loss of “traditional aesthetics” of the area (for lack of a better term).”

In addition to gains in knowledge, students also benefited from improvement in their skills in addressing urban problems. As depicted in Fig. 4, students’ “comfort level with various techniques of urban observation”, “comfort level with interviewing people in urban settings”, “comfort level of building prototypes in urban settings” and
“comfort level of working with community partners” all improved significantly ($t = 3.568, 2.201, 5.104, 2.476, p = 0.002, 0.022, 0.000, 0.013$, respectively). “I learned about different methods of closely looking into urban settings. Each of them gives a different perspective to a space, even though I have known that space for a long time”, written by one student in his reflection. “We have to respect people when we interview them. It’s important to consider people’s feeling and do our best to make them comfortable. Just talk with them in a normal way, like a friend.”, another student noted. The results indicated that this educational experience has better prepared students to master the skills that they will repeatedly use when addressing real-world urban issues after they graduate.

5.2. Interdisciplinary collaboration

As shown in Table 1, the academic background of the students attending this course over the past two years ranged across over fourteen majors. It was envisioned that the students would bring diverse perspectives, thoughts and skills to their teams that would lead to comprehensive recognition, definition, analysis and resolution of urban challenges in their term projects. As depicted in Fig. 5, student ratings of “comfort level of working with people from different disciplines” marginally improved over the course (mean ratings from 4.00 to 4.33, $t = 1.234, p = 0.119$). The statistical insignificance of the improvement may be because the initial level of comfort was already high. Student ratings of “competence about working with people from different disciplines” increased steadily (mean ratings from 3.53 to 4.13, $t = 3.674, p = 0.001$). A total of 80.0% students reported positive or no change in both comfort level and competence of working with people from different disciplines, and among them, 53.3% students reported positive changes in both indicators.

The above results indicated that, despite various challenges in interdisciplinary collaboration in virtual environments (Rosenman, Smith, Maher, Ding, & Marchant, 2007), the majority of students generally enjoyed and benefited from such collaboration. Some of them reported in course questionnaires and reflections that “working together in an interdisciplinary and multi-national team of ambitious and enthusiastic students helped me to see various issues and aspects about Beijing from different points of views”, “I find that cooperation really encourages people to make progress, especially when the teammates are from different majors”, and “I find it is joyful to work with people with different background”.

Meanwhile, three students, or 20.0% of total respondents, indicated negative changes in the comfort level of working with people from different disciplines, although they all reported that they felt more comfortable with interdisciplinary collaboration after the studio and their competence of interdisciplinary collaboration continuously increased throughout the course. The complaints from these three students were mostly related to language and dealing with internal disputes that caused project delays. Certain difficulties were observed as expected in the collaboration. For instance, some design students were unfamiliar with methods employed by engineering students in problem investigation. Teams occasionally had vigorous discussions about which directions to pursue for prototype design and visualization. There were also debates about the effectiveness and policy implications of alternative solutions. Despite the fact that the above difficulties may have slowed down the development of the term projects and caused discomfort among some students, the faculty believe that there is a positive way to look at these difficulties. In fact, these are common challenges that scholars and professionals working on cross-disciplinary urban problems in the real world are constantly facing. Students, in turn, are able to learn soft skills and manage interpersonal matters and conflicts. Exposing students to challenges in a mutual learning educational setting is perhaps the best way to prepare them for real-life challenges in their future careers (Clark & Button, 2011) and may lead to more effective future solutions in urban sustainability (Steiner & Posch, 2006).

5.3. Cross-cultural comparative study

The students who attended in this course over the past two years included nationals from nine different countries. The course was envisioned to provide students with a multi-cultural learning environment where they can discuss and compare urban issues that different cultures face. The responses from the students to two questions in the questionnaire suggested that this objective was generally achieved. As
depicted in Fig. 6, their ratings of “comfort level of working with people from different cultures” and “competence about working with people from different cultures” both increased significantly, as the mean ratings increased from 3.47 to 3.20 at the beginning of the course to 4.07 and 4.00 at the end of the course (t = 2.201, 3.292, p = 0.022, 0.003, respectively). A total of 86.7% students reported positive or no change in the comfort level and competence of working with people from different cultures, and among them, 66.7% students reported positive changes in both indicators. Two students, or 13.3% of total respondents, reported negative changes in the comfort level or competence of working with people from different cultures after the course.

Throughout the process, the students were encouraged to conduct comparative studies using both Beijing and the Bay Area as two cases. The objective was not only to let the students experience, exchange, and compare the status quo of urban development in both cases, deepening their understanding of respective urban sustainability challenges in developed and developing economics, but also to encourage students to think outside the box and expose them to different perspectives and opinions in the process of achieving their project goals. It was observed that the students generally showed interest and progress in adopting a comparative perspective in their chosen urban challenges. For instance, the Clean Air Asia team surveyed senior citizens in Beijing and the Bay Area and analyzed the difference of respondents in awareness and concerns of the air pollution problem given the distinct air quality conditions between Beijing and the Bay Area. The City of Cycles team also compared the mobility situations in both cases and concluded that Beijing and the Bay Area faced common challenges such as decreasing usage of non-motorized modes of transportation and intensifying...
congestion and environmental concerns.

Several challenges were observed. First, the project scope was overly reliant on field data collection and prototype testing that could only be carried out by one side of the team for the majority of the time during the first course iteration, such that the propositions from Stanford students were not always implemented in the fieldwork by their Tsinghua teammates and some Tsinghua students desired more exposure to the U.S. context, which they felt was not achieved by working on Beijing-based projects. This motivated the restructuring of term projects in the second course iteration. Second, a student complained in that “the most challenging about the course is to deal with troubling group mates and egoists.” Another student complained that “the most challenging aspect was divvying up group responsibilities equitably.” These challenges may explain an interesting result in the questionnaire that the mean rating of comfort level of working with people from different cultures had a trend towards decline during the term projects (mean ratings from 4.13 4.07, t = 0.250, p = 0.403). While most students reported positive or no changes in their comfort level during this period, four students, or 26.7% of total respondents, reported large negative changes, although all of them reported that they felt more comfortable with cross-cultural collaboration after the studio. It is also interesting to note that, the two students who reported negative changes in their comfort level of working with people from different cultures both reported 5 points, the highest score, in a five-point Likert-scale question at the beginning of the course. It is likely that these students were overly optimistic or confident about cross-cultural collaboration. Through this educational experience, they have improved their awareness and ability to navigate possible challenges such that they are now more realistic and prepared to handle similar circumstances and future collaborations.

Despite all these challenges, it is reassuring, however, that the questionnaire results suggest while a few students’ comfort level with cross-culture teamwork fluctuated throughout the course, their self-reported competence about working with people from different cultures continuously increased. Therefore, these results may suggest that students did grow and ultimately derived positive benefits from difficult situations.

5.4. Improvements for future course iterations

With the course on track to be offered in subsequent years, there remains room for improvement in future course iterations. In particular, students have mentioned improving the joint teleconference sessions. Some students have mentioned that it can be difficult to stay engaged during the teleconference sessions that involve the whole class; instead, they expressed greater satisfaction with small group discussions where it is possible to hear and respond to each person on the team.

There is also the possibility of creating greater parity in the number of in-classroom instruction hours and faculty exposure on both Tsinghua and Stanford sides. Due to different number of credits this course offers on both sides, each week, Stanford students are required to attend two afternoon sessions in addition to a 3-h evening lab where the joint teleconference takes place, while Tsinghua students meet once a week for only the 3-h joint session. The additional 3 h per week enable the Stanford students to delve further into urban sustainability literature and case studies. More in-class discussion between faculty and their peers in the classroom can also enhance their overall learning experience and satisfaction with the course.

Finally, the course is intended to guide students to examine urban sustainability through the lens of social sciences, analyze the problems and test their solutions using engineering methods, and develop prototypes and narratives using human-centered design thinking. The syllabus and urban labs strongly reflected the social sciences and design background, but the framing of engineering methods and practice was not as pronounced despite the strong background of two faculty members in the hard sciences. Future course iterations may want to consider implementing more readings or assignments that hone the ability of interdisciplinary students to develop engineering mindsets.

5.5. Future research on urban sustainability

As the definition of urban sustainability expands to include metrics of social sustainability, the responsibility of preparing the next generation of sustainability scholars and practitioners will fall upon academia. To nurture this pipeline, it is necessary to adapt new teaching principles and approaches as detailed in this paper. However, the authors caution against taking a myopic view of only the students, which obscures other players in the ecosystem, such as faculty, NGOs, and government agencies that provide the real-world partnership and context for these courses. Faculty with practitioner backgrounds can uniquely guide their students’ work and influence the range of practical and analytical methods that students use for their projects. As a benefit, faculty can stay connected to real-world practice and maintain a connection to projects outside of academia. External project partners also vary in nature from small NGOs to larger established public sector agencies, and it is important to examine how these various organizations approach the course with different expectations for how they work with students and their ability to use the project deliverables at the end of the course. Future research will explore the perspectives, contributions, and experiences of the community partners, and ultimately, whether the offering of such curricula can result in actual and improved outcomes in urban sustainability.

6. Conclusions

The emerging and heightening challenges in urban sustainability that arise from various aspects spanning from environment to energy resources, infrastructure and human communities require holistic comprehension of cities in a global perspective and actionable approaches through interdisciplinary collaboration. This paper describes the experiences that the authors had in teaching a university course to educate young academics and future professionals about sustainability of urban regions that are under rapid economic, social and environmental changes (Vaz, 2016). The course was taught within an interdisciplinary and cross-cultural setting through a project-based and self-regulated process that infuses human-centered design. To achieve this objective, major pedagogical challenges were identified and a number of teaching principles were integrated and experimented in this course. Based on a review of the past two course iterations and assessment of teaching outcomes, lessons learned in this teaching experience, in terms of primary challenges in urban sustainability education, effectiveness of the adopted teaching principles, and directions for future improvement, were discussed. Such experience and lessons learned can hopefully benefit the development of similar courses to foster sustainability education in urban and regional sciences and relevant domains around the world, and ultimately contribute to actual and improved outcomes in urban sustainability in developed and developing economies alike.

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