

Fostering Holistic Competencies, Global Citizenship, and Innovation in Engineering Students through Community Outreach to Disadvantaged User Groups

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Abstract—The current work-in-progress paper reports an on-going implementation of a capstone project course that aims to develop holistic competencies and global citizenship in engineering students through innovations and community outreach to disadvantaged user groups. This work is part of a larger on-going joint university project in Hong Kong. Six universities across a variety of disciplines have participated in the project; which targets to identify effective pedagogies and assessment methods for holistic competencies, and to collect the evidence of students' holistic competencies development. The focus is placed on engineering students and their learning in the current ongoing study. The project objectives are implemented by integrating community outreach activities and capstone project experience to foster context-driven innovation in engineering students. The paper also reports two projects completed by the student participants, namely the development of a context-aware alternative and augmentative communication system for children with intellectual disability; and the implementation of a cloud communication system for people with complex communication needs. Our work is amongst the early attempts to understand and promote holistic competencies and global citizenship development in engineering students.

Keywords—*holistic competencies; global citizenship; innovation and design; diversity; users with special needs*

I. INTRODUCTION

While the world undergoes rapid economic, social, and environmental changes nowadays, the technology advances to address the changes accordingly. However, there are still arising global challenges such as inequalities in infrastructure, health, and education [1], resulting in a need for universities to prepare students with the skills for hunting jobs and coping with technologies or potential problems that are yet to be known [2]. Being aware of such needs, the United Nations (UN) announced a set of 17 Sustainable Development Goals (SDGs) in December 2015 in “*Transforming our world: the 2030 Agenda for Sustainable Development*” [3]. These universal and transformative SDGs attempt to address a range of immense global challenges such as to promote inclusive and equitable quality education, to diminish inequality within and among countries, and to achieve gender equality. In addition to the dissemination of disciplinary knowledge, engineering educators have been called to nurture their graduates' attitude and competencies to achieve the SDGs [4],

meaning that engineering educators are entrusted to foster holistic competencies and innovations in students and to breed them as global citizens in the world of diversity.

A. Related Works

As it is expected that Engineering programmes are to cultivate graduates' ability to apply engineering knowledge to address diverse societal needs, service learning has been implemented into the engineering curricula in many different universities (e.g., [5] – [7]) to expose students to diverse learning environments across the community [8]. For example, the Engineering Projects in Community Service (EPICS) programme founded at Purdue University in 1995 [6] has now been scaled up to a worldwide effort in IEEE [9]. There are currently over 50 projects implemented around the globe, from building devices to assist communication for the disabled users in India to promoting rural education with renewable energy in Kenya. Meanwhile, educational research studies report that students' participation in service learning promotes their social responsibility attitudes [10] and diversity awareness [11]. It is also suggested that service learning can effectively promote students' global citizenship and international mindedness [12].

B. Our Contribution and Significance

The current work-in-progress builds on well-established service learning frameworks (e.g., [6] – [9]) and aims to introduce holistic competencies and the achievement of UN SDGs as two new components in engineering students' service learning. This paper would thus report the design and implementation framework of a capstone project course themed “Information Engineering for Better Living” at a university in Hong Kong. Two case studies of capstone projects are also provided to demonstrate how the community outreach to the disadvantaged user groups can foster holistic competencies, global citizenship, and innovations in engineering students.

II. BACKGROUND AND THEORETICAL FRAMEWORK

A. Holistic Competencies in Engineering Education Context

“Holistic competencies” refers to a set of competencies for holistic human development [13]. It comprises of knowledge,

values and skills, as well as personal competence such as “resilience”, “empathy, self-confidence, persistence” and “listening skills” (p.112). Students with well-developed holistic competencies are not only keen in academic study, but also kind in personality. Having holistic competencies developed in students echoes the goals of the Education Bureau in Hong Kong (e.g., [14]). In order to develop holistic competencies in engineering students, corresponding educational endeavors are demanded to enhance three types of skills: (1) foundation skills such as the subject knowledge and skills acquired through formal engineering education, (2) specialized skills and specific “know-how” acquire beyond classrooms, and (3) transversal skills which are non-disciplinary-specific but are necessary for a wide variety of real world situations and work settings.

B. Global Citizenship and Sustainable Development

Global citizenship, referring to a sense of belonging to a broader community across disciplines and national boundaries [15], is a core transversal skill. It involves positive attitudes including the respect for diversity and intercultural understanding [16], which are found to be increasingly demanded from engineering graduates [17]. Alongside the announcement of UN SDGs [3], engineering educators are encouraged to take up a leading role in ensuring that their graduates are competent in applying engineering knowledge for achieving the SDGs [18]. An early effort has been reported recently; where the learning objectives for SDGs are integrated in the cognitive, socio-emotional, and behavioral domains at course level [19].

C. Design Thinking, Innovation, and Diversity in Engineering Capstone Projects

Engineering design can be regarded as a systematic and intelligent process since the functions for applications and systems addressing societal needs or objectives are generated, defined, and evaluated under a specified set of constraints [20]. Effective pedagogical approaches to engineering design thinking are mainly subjected to divergent-convergent questioning (p. 104), recognition of system contexts and dynamics, reasoning about uncertainty, making estimates, and conducting experiments (p.105). Given that engineering design involves multiple socio-technical dimensions [21], it is acknowledged that innovation requires the collaboration among team members, including those who are technologically underrepresented [22]. Consequently, the engineering community can also benefit from interaction with users from a diverse background including the disadvantaged ones. Apart from raising the diversity awareness in students, the design project experience can be effectively introduced to students through service-learning based capstone courses [23] as they work on projects for not-for-profit clients and bring about social impacts by working out innovative solutions to address people’s needs.

D. The Current Work

The current work is motivated by the illustrated effectiveness of design thinking pedagogies, as well as the pressing needs for addressing the global challenges such as

inequalities, poverty, and social exclusion. It is a work-in-progress that seeks to foster holistic competencies, global citizenship, and innovations in engineering students through capstone projects within the formal engineering curriculum. Our implementation is guided by the following research questions (RQs):

1. (RQ 1) How can holistic competencies and global citizenship be developed in the context of capstone projects?

2. (RQ 2) What are the pedagogical implications of our implementation to engineering education for fostering innovation through diversity?

III. IMPLEMENTATION

Our work takes place in a credit-bearing capstone project course offered in an undergraduate engineering curriculum. It is provided as an option to the students hoping to use their capstone project experience as an opportunity to serve the underprivileged groups in society. The purposes of the theme, Information Engineering for Better Living, are to enrich engineering students’ capstone experience with their whole person development and community outreach learning; and to promote their design thinking as they attempt to develop innovative solutions to improve the life of people with diverse needs. The key learning activities include (figure 1):

- Participating in a 5-day-and-4-night residential camp for holistic competencies development (June 2018)
- Carrying out capstone projects (Sept 2018 to May 2019)
- Having community outreach for disadvantaged user groups and contextual field studies (entire project period)
- Joining regular supervisor-supervisee project meetings and project implementation (entire project period)

Having noted that individual faculty members from the hosting department have begun the implementation trials in their capstone courses since 2013, these scattered efforts are gathered under the umbrella theme “Information Engineering (IE) for Better Living” since 2018/19.

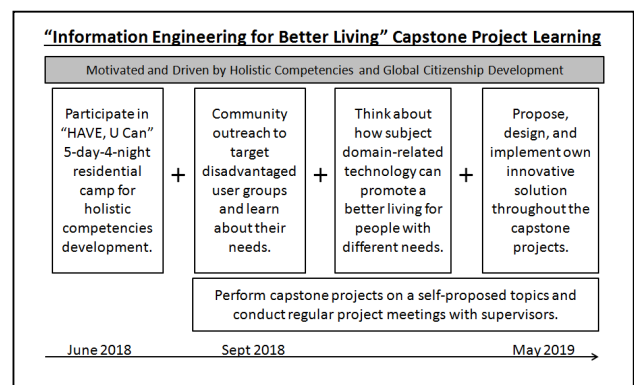


Fig. 1. The overall implementation framework (2018-2019).

A. HAVE, U CAN Programme for Holistic Competencies Development

Students participating in the capstone project are required to join the HAVE, U Can Programme [24]. The programme is collaborated among six local universities in Hong Kong. It is a five-day-and-four-night event organized for undergraduate students ($N = 200$) majoring in different disciplines including engineering. The programme aims to promote tertiary students' holistic competencies and positive virtues through the following activities:

- Experiential and reflective learning activities (e.g., "Stories of Hong Kong People" and "Letter to the Future Me")
- Training workshops (e.g., "What is Reflection")
- Residential and mentoring experiences
- Social events (such as team-building activities and a high table dinner with guests from the industry and NGOs)

During the camp experience, freshmen and sophomores (Year 1 and 2) are grouped in teams of five to six and mentored by their senior fellows (Year 3 and 4). All of them are provided with ample opportunities to learn and get along with one another. They do not only have their holistic competencies developed and trained in a series of student-centered activities, but also experience residential education through living with their peers at university halls.

B. Community Outreach and Contextual Field Studies

As a part of their learning experience, students will reach out to the community beyond the campus (such as rehabilitation centers and special education schools) and gain an understanding of the efforts engineers may make to address societal needs. Meanwhile, through face-to-face interactions with target users, care-givers, and professionals such as speech therapists and teachers at special education schools, engineering students would be given opportunities to engage the non-engineering stakeholders from the community into the engineering design thinking process. The community outreach activities are a critical component in Human-Computer Interaction (HCI) research [25] because it serves as contextual field inquiries and studies for HCI designers to directly observe the implementation environments and understand their users' needs. It also addresses the expected graduate outcomes such as "an ability to design a system, component, or process to meet desired needs", and "to understand the impact of engineering solutions in a global, economic, environmental, and societal context" [26].

C. Capstone Project Learning

Students will carry out their capstone project learning (preferably in a team of 2 to 3 members) throughout the entire academic year. During which they will partake in regular project meetings with their primary project supervisors. Professionals from the community service providers such as speech therapists and occupation therapists are also invited to be the co-advisors for the projects. In addition to community outreach to people with diverse needs, students will also think about how the subject domain knowledge gained from

Information Engineering courses can be applied to promote a better living standard for the target disadvantaged user groups. Particularly, they will propose, design, and implement their own innovative solutions under the facilitation and guidance of the primary project supervisors throughout the capstone course. Students are required to conduct two poster presentations, respectively at the end of the first semester and at the end of the second semester, and then submit a thesis to conclude their work.

IV. CAPSTONE PROJECT EXAMPLES

As mentioned in Section III, prior trials in capstone projects have been performed by the first author since 2013. Two such projects are illustrated in this section.

A. Project One: Augmentative and Alternative Communication for Users with Communication Needs

Having seen that people with complex communication needs [27] have a severe limitation in their daily communication functioning and thus often rely on augmentative and alternative communication (AAC) methods to supplement or replace verbal communication [28], a group of final-year students supervised by the first author performed a capstone project that aims to implement a cloud AAC system for users with complex communication needs. The project was collaborated with a major non-profit organization serving people with various types and levels of cerebral palsy (including spastic and dyskinetic cerebral palsy) in Hong Kong. The target users of the system were patients diagnosed with clinical conditions such as deafness or severe hearing loss, and Down's syndrome. Throughout the 9-month project period (September 2015 to May 2016), students underwent extensive exchanges with speech therapists and occupation therapists and developed a component within the cloud AAC platform. The invention enables people with severe communication disabilities to conduct telephone-like conversations [29] (figure 2). The project mainly addressed SDG number 3 "Good Health and Well-Being" specified by the United Nations.



Fig. 2. Partial implementation of a cloud AAC system for people with complex communication needs by the capstone project students.

B. Project Two: Context-Aware Communication Systems for Students with Intellectual Disabilities

While the communication and language usage are often context-dependent [30], children and adults with intellectual disabilities find it hard to sustain the communication because of their significantly limited verbal working memory [31]. In the second project, two groups of final year project students supervised by the first author conducted their capstone project in 2016-2017 by visiting a special education school serving students with moderate intellectual disability (IQ ranged between 40 and 55). Besides the school visit, the engineering students engaged in a series of on-site contextual field studies and design meetings with school teachers. They implemented a context-aware AAC system using the Bluetooth Low Energy (BLE) technology. The project innovates by enhancing the quality of existing AAC solutions with iBeacon-based ranging and micro-location detection capabilities, reducing the cognitive load demanded from the users. With the help from the school teachers, the project students performed a series of trials with the users from the school (figure 3). The project hence directly corresponds to UN SDG number 4, “Quality Education”. All of the participating students reflected that the project experience was very meaningful and helpful to their engineering learning.

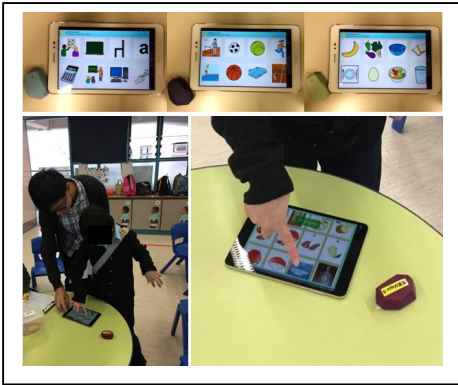


Fig. 3. Capstone project students visited a special education school and developed a context-aware AAC system for users with intellectual disabilities.

V. DISCUSSION

A. Developing Holistic Competencies and Global Citizenship in Engineering Students through Capstone Projects

Both cornerstone and capstone projects provide first-hand design experiences to students, in which virtues and social impacts are also emphasized [23]. In two illustrated capstone project cases, learning objectives in the cognitive, socio-emotional and behavioral domains of holistic competencies and global citizenship have been implemented. It is clear that the projects helped promote students' understanding of engineers' professional responsibilities in promoting an inclusive society and the impact of engineering solutions in a global and societal context. Lastly, students could seize the initiative in designing and implementing their innovative solutions for their target users in the community.

B. Fostering Innovation in Engineering Students through Diversity and Community Outreach and Engagement

Community outreach provides an opportunity for students to interact with people from different backgrounds, and to learn about their diverse needs. In the abovementioned implementation cases, students went beyond ordinary learning environment and worked with community partners such as the rehabilitation centers and special education schools. Through onsite contextual field studies and inquiries, the students engaged into face-to-face interactions with special needs user groups and their caregivers. These experiences encouraged students to propose and implement innovations in areas such as assistive technologies and ambient communications (e.g., [29], [32]) upon gaining a first handed understanding of the users' special needs.

C. Limitation and Future Work

This subsection presents the attempt to address the limitation in this work-in-progress and direction for the authors' future works. As an on-going work (figure 1), the implementation of the entire capstone project learning experience is expected to be completed in May 2019. Therefore, the evidence of how the learning experience enhances the skills (holistic competencies, global citizenship, and innovation) in the participating students has not yet been available. Nevertheless, the project team (consisting of educational researchers and engineering faculties) has defined an assessment scheme to evaluate the impact of the “HAVE, U CAN programme” and the “IE for Better Living” capstone experience on participants' holistic competencies and global citizenship development. Direct evidence (including students' reflective essays, project reports and deliverables) and indirect evidence (including semi-structured interviews and a questionnaire survey using a validated instrument developed by the third author [33]) will be collected and evaluated.

VI. CONCLUSION

The current work is an on-going effort in promoting engineering students' holistic competencies and global citizenship development. By outreaching to the disadvantaged user groups and learning about their needs, students were also aspired to propose and implement innovative solutions for the target users. Our early implementation efforts have been in place since 2013 and these endeavors are further extended to an initiative titled “IE for Better Living” that has launched in June 2018. Follow-up educational research studies will be conducted to examine the effect of community outreach on engineering students' learning.

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