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Exploring Maker Innovation: A Transdisciplinary Engineering Design Perspective

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Abstract: Researchers, designers, and engineers embrace the ongoing maker movement and view 'grassroots innovation' as essentially important for staying competitive in both academia and in industry. The research team gives full play to its expertise on innovation and entrepreneurship education. In the past five years of actively participating in the China-U.S. Young Maker Competition, the team coached and worked with over five hundred student makers to create innovative engineering prototypes focusing on the areas of community development, education, environmental protection, health and fitness, energy, transportation, and other areas of sustainable development by combining innovative design and emerging technologies. Several conceptual designs and developments are described. A transdisciplinary engineering design and teaching approach is presented and discussed. Due to the limited time allowed by the competition, more thorough design and development iterations will take place in a future study.

Keywords: maker innovation; emerging technologies; engineering design; transdisciplinary teaching and learning

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1. Introduction

In recent years, a wide range of maker activities have been carried out as part of a growing cultural phenomenon among young people, such as technology geeks, creative thinkers, artists, hobbyists, science enthusiasts, and inventors [1–5]. These activities actively transform scientific research results, catalyze innovation of traditional education, produce social and industrial benefits, and provide a broad innovation-culture platform. They are now increasing in a growing innovation movement characterized by community, creativity, and openness [6–8]. In this paper, maker innovation refers to: (1) paradigm shifts and pushing the boundaries of transdisciplinary innovations, (2) exploring major technology trends and engineering design opportunities that promote student makers, (3) changing the world by changing the ways in which people see and interact with the world.

Pioneering institutes in cities worldwide have explored ways to introduce the maker spirit by launching experimental programs focusing on fabrication, innovation, and teamworking. Makerspaces, makerfairs, and engineering design contests have gained in popularity. The Bechtel Innovation Design Center at Purdue University is a multi-level building with a student-focused, peer-mentored, as-needed, educational community across disciplines (purdue.edu/bidc, accessed on 12 December 2021). Dozens of makerspaces are spread throughout the Stanford University campus, including small rooms designed to support research into huge facilities and help students and faculty explore their inner makers, while also supporting those who are experienced creators (maker.stanford.edu, accessed on 12 December 2021). The D:DREAM hall at the Delft University of Technology houses highly motivated students who are responsible for all tasks from team management to the design and production of their inventions (tudelft.nl/en/ddream, accessed on 12 December 2021). Although such makerspaces at universities have different purposes, they all provide similar opportunities and challenges for their students to: (1) practice the 'learning by doing' philosophy [9], (2) use advanced equipment and tools, (3) meet and collaborate, (4) participate in makerfairs and contests, and (5) be mentored, supervised, and guided by experienced coaches.

In the current Chinese context, innovation and entrepreneurship are identified as the new drivers for economic growth by encouraging and complementing the energies of individuals and markets (english.gov.cn/makersandinnovations, accessed on 11 November 2021). Instead of being seen as the world's factory, China wants to be seen as the center of design and innovation. A group of entrepreneurial platforms and angel investment institutions are planned to be fostered. The plan aims to mature makerspaces and nurture the spirit of entrepreneurship. Looking at the current education settings, most teachers are accustomed to the established curriculum and straightforward instructing style; they are reluctant to engage with students proactively and adopt project-based coaching [10]. Promoting maker innovation and education is still a difficult task at this moment.

Several research institutes have established maker education frameworks of innovation and entrepreneurship that integrate teaching practice, independent learning, guidance and assistance, cultural exchanges, and global frontiers [11–13]. Practical education for engineering design is available to students who are encouraged to participate in creative projects to enhance their innovation and entrepreneurship capabilities. Based on the characteristics of Chinese students' cognitive development [14], these diversified and dynamic education frameworks integrate multiple learning stages across elementary school, middle school, undergraduate and postgraduate education to complete new missions to cultivate talent for the creative industry [15–17]. Researchers, designers, and engineers give full play to the advantages of disciplines and establish both online and on-site communities responsible for planning, organizing, coordinating, guiding, monitoring, and evaluating projects. Putting an emphasis on cultivating students' critical and creative thinking and making, they carry out project-based maker activities extensively and encourage coaches to bring cutting-edge technologies, the latest research results, and hands-on experience into makerspaces. In these makerspaces, students typically work in teams to develop good communication skills and innovative spirits. They are often encouraged to go out of the space to participate in maker competitions.

2. Methods

2.1. The Maker Competition as the Research Context

Cognitive styles influence learning strategies and affect students' learning performance. 'Co-Making the Future', the China–U.S. Young Maker Competition (chinaus-maker.org.cn, accessed on 11 November 2021) is an activity supporting China–U.S. Social and Cultural Dialogue [18]. The competition has been held annually since 2014, serving as a platform to enhance exchange and friendship between Chinese and American young people and to unleash the innovative and entrepreneurial spirit. A panel of qualified judges select finalists from both nations to compete in the final stage in Beijing. (Note: Due to the COVID-19 situation, the 2020 and 2021 final stages were held in an online format). Contestants' projects are reviewed and scored by the judges according to four criteria as follows: (1) innovation and creativity, i.e., can the project solve specific social and livelihood problems, or create new opportunities for solving the problem?; (2) completeness, i.e., does the project provide an effective problem-solving solution, and is the solution clear and complete?; (3) technical rationality, i.e., can the technical route used in the work satisfy the realization of its intended function?; and (4) application prospects, i.e., can the project develop into an entrepreneurship program?

2.2. The Transdisciplinary Approach

While many traditional engineering innovations still draw heavily on experimental labs of multidisciplinary teams, efforts to define inter- and transdisciplinary engagement have been the focus of many emerging engineering design disciplines [19–22]. Key characteristics of transdisciplinary research include: (1) integrating knowledge from several disciplines, (2) collaborating in engineering design activities, (3) defining down-to-earth problems in everyday life, (4) designing innovative solutions, and (5) developing, extending, and applying new knowledge to other contexts. The research team promotes innovation and entrepreneurship education and explores how education, psychology, design, technology, and business could be integrated. The aim is to support the design and development of new products, services, and systems in the conceptual design phase by developing innovative methods and techniques, fostering human centered designers, and leading transdisciplinary projects. Our main research directions include design psychology, human factors, user research, tangible and embodied interaction design, and usability evaluations.

2.3. Double Degree and Exchange Programs

To promote global, collaborative, and transdisciplinary teaching and learning, several double degree and exchange programs have been established, driven by the desire to explore maker innovation over the past five years. For example, a graduate level double degree program in user experience design at the School of Design and Creative Arts at the Loughborough University (lboro.ac.uk/schools/design-creative-arts, accessed on 12 December 2021), combines empirical methods of data analysis with empathy-centered skills. The goals are to: (1) develop empathic digital products and services based on design-thinking models and negotiation of conflicting user perspectives; (2) appraise user-centered design's fundamental research techniques to investigate emotional and cognitive experiences; (3) synthesize usability evaluation, website design, and psychology to make informed judgements on iterative designs; (4) support the student's creative, analytical, or technological skills growth within design or innovation contexts; (5) construct sophisticated human-machine prototypes with the aid of statistics, advanced usability principles, data analytics, and experimental prototyping techniques; (6) design innovative solutions to society's complex problems while collaborating with other engineering specialities; and (7) develop original research into unsolved and novel human-computer interaction problems.

3. Results of Exploring Technology-Inspired Design

The competition requires competence in both product design and computer engineering. With new technologies coming up, such as virtual reality (VR), augmented reality (AR), mixed reality (MR), extended reality (XR), artificial intelligence (AI), big data, new materials, digitalization, etc., it is possible to generate better design outcomes in terms of products, vehicles, buildings, systems, etc. These outcomes can be safer, more comfortable, and provide new interactions and functionalities to a wide range of users [23]. Not only are people confronted with many new technologies, there are also many developments regarding design processes, methods, and tools [24]. These have profound impacts on the design teams, on manufacturing, and on supply chains. Therefore, demonstrating the application of new emerging technologies, as well as new design processes, is essential to lead designers, engineers, and researchers to generate better design outcomes.

To establish maker competition in a down-to-earth research and design context, several experiential prototyping practices [25,26] have been committed to cultivating both innovative research and entrepreneurial talents in our institute since 2016. The research team closely collaborates with both national and international innovation companies. The research design focuses on target user groups, context of use [27], emotional indicators [28], meaningful interactions [29], new technologies, and human factors [30]. Each year, a total of three iterations of concept and prototype development were made. The first iteration focused on exploring conceptual possibilities and building initial prototypes. The second iteration aimed to crack the hardest technological problems and further develop the concept to a mature level. The third iteration involved users and user comments to finalize the prototypes. Table 1 shows how technology-inspired engineering designs are distributed over five experiential prototypes, in which contexts, characteristics, and technologies are applied to demonstrate the designs.

Table 1. Distribution of contexts of use, characteristics of the user system interactions, and emerging technologies.

Prototype	Context	Characteristic	Technology
The aha	Home	Engaging, encouraging, personalized, flexible	Electroencephalograms (EEG), inhibition of return (IoR), Raspberry Pi, voice module, galvanic skin response (GSR) module
The Alert Node	Forest	Long-lasting, reliable, accurate	Laser dust sensor, long range (LoRa)
The Hola Hoop	Work, home, commute	Adjustable, playful, customized	Mpu6050 six-axis sensor, Kalman Filter, Arduino
The Guardian	Commute	Invisible, real-time, automatic	Raspberry Pi, NVIDIA Jetson Nano, infrared binocular camera, GSM/GNSS/GPRS
The Bravo	Work, home, commute	Natural, relaxed, encouraging	Heart rate sensor, vector sensor, skin sensor

3.1. The Aha

Cognitive styles influence learning strategies and affect students' learning performance. Parents generally pay attention to their children's academic performance and expect them to improve, but pay less attention to their cognitive style, thus failing to set effective learning strategies. The Aha learning aid prototype is designed by Beixuan Huang, Dan Zhu, and Jingjing Zhu, who were contestants in 2021, to help parents understand their children's cognitive characteristics in order to develop learning strategies and improve students' interest in learning. Cognitive styles can be divided into field dependence (FD), field independence (FI), contemplation, and impulsive [31]. During the learning stage, the cognitive styles are mostly the FD and the FI type. The characteristics of FD students include: (1) guided by external factors, they are more dependent on external objective things; (2) easily disturbed by the external environment and cannot maintain a stable learning state for a long time; (3) tend to accept knowledge passively; (4) not good at handling details. The characteristics of the FI students include: (1) dominated by internal factors, they are more dependent on internal subjective consciousness; (2) in the learning process, the learning state is relatively stable, with little interference from external factors; (3) highly independent, they can actively think independently to solve problems; (4) have a clear learning plan.

Based on contextual user research, the Aha iterates and includes the following features: (1) it recognizes children's different cognitive styles and guides parents to recognize their children's needs, providing personalized teaching materials; (2) it is collaborative and interactive through inviting multiple students to complete learning tasks together; (3) the presentation of information is engaging, encouraging, and personalized; (4) the monitoring and dynamic feedback observe children's learning status in real-time situations; (5) it is portable and flexible.

In terms of software and hardware engineering design, the Aha consists of two main components, as shown in Figure 1: (1) a cognitive style recognition based on EEG and (2) an IOR teaching mode based on laser touch technology. The hardware consists of four parts: (1) an EEG acquisition module, (2) an amplifier, (3) a mobile application, and (4) a laser touch device. Multiple tasks are designed to discover whether different FD and FI cognitive styles can be reflected in differences in event-related potentials (ERP) activities. The head-mounted EEG records the FD and FI data and analyzes N270 components to judge these cognitive styles. A microcontroller unit (MCU) transmits the data to smartphones and a cloud platform through wireless technology. The laser touch technology is applied to create a 'field' environment and to establish a user-friendly atmosphere in a family context.

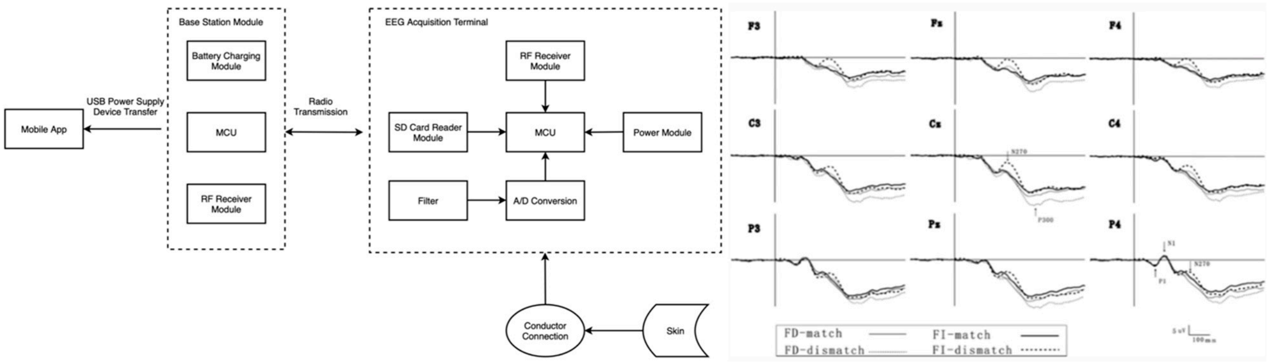

Figure 1. Left: the software and hardware structure diagram. **Right**: the recorded FD and FI activities.

In constructing the 'field', with a child's work desk and a LED lamp, a low-fidelity prototype is also equipped with a Raspberry Pi and a voice module, along with a GSR module. Recording data to an external sound card, the voice module converts the data into text and controls the transformation of the LED lights and the realization of the 'field' after recognizing the voices, as shown in Figure 2. The Raspberry Pi is connected with the EEG identification module as a wearable product. After several rounds of quick user and technology testing sessions, the GSR module is found to be redundant, thus it is removed from the final high-fidelity prototype.

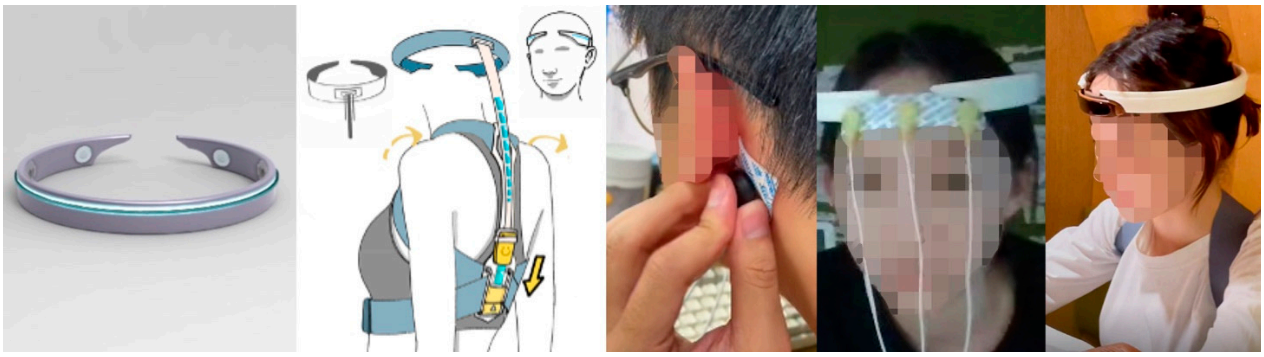

Figure 2. From left to right: the engineering design renderings, the assembly schematics, the GSR module, the low-fidelity prototype with the technologies, and the high-fidelity prototype with the technologies embedded.

3.2. The Forest Alert Node

Forest alerts are small, cheap, and efficient Internet of Things (IoT) devices that are dropped from a plane or helicopter deep into a forest and alert the authorities when a fire is detected. Current fire detection systems require a large infrastructure setup. A new system was designed by Wesley Eccles, who was a contestant in 2021, to drop and forget for a significantly lower cost. The system is designed to access areas of the forest that otherwise would not admit of any type of ground detection system. As shown in Figure 3, the main form of detection is from a Laser Dust sensor within each node device. The sensor checks for certain concentrations of smoke particles in the air. Mixing that data with the temperature and/or humidity, it runs through an algorithm to determine if it believes there is a high likelihood of a fire in the surrounding area. If a fire is detected, it sends that data and an alert to the base station through the different nodes. Each node sends a signal back when they receive an alert, confirming that the transmission was successful. To try and reuse some of the devices when their lifecycle is over, each node could be outfitted with a hiker tag. This tag has the expiration date for when the lifespan of the device is supposed to end printed on top. If someone happens to find the device in the forest, they can pick it up and ship it back using a prepaid label inside of it. This helps cut down on these devices collecting in the forest over time and lets hikers know why the devices are there in the first place. No maintenance or ground access is needed to deploy the system. Using LoRa to communicate between nodes, the system is equipped with multiple sensors that detect a wildfire before it gets out of hand and sends that information to a fire response team, as shown in Figure 4. This system can detect a fire fast and accurately before it spreads and gets out of control.

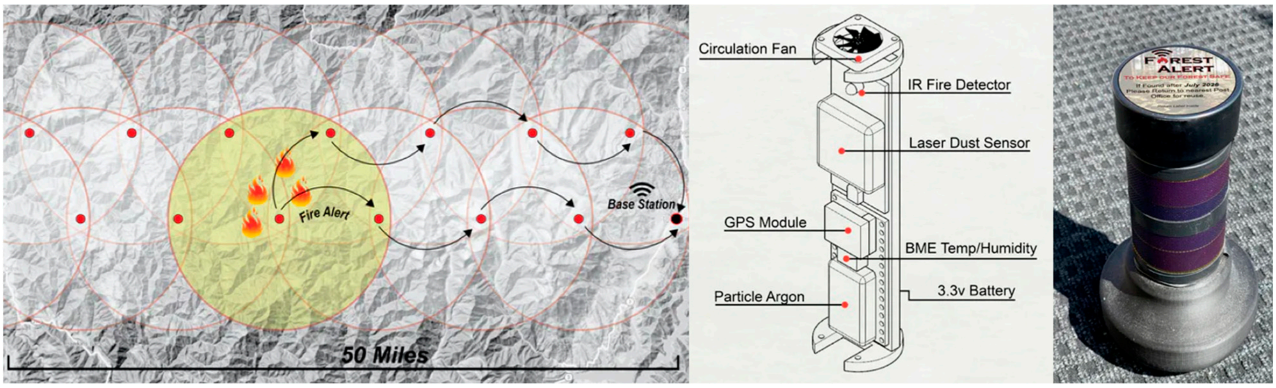

Figure 3. **Left**: the node-based communication diagram. **Middle**: the components. **Right**: the prototype and the hiker tag.

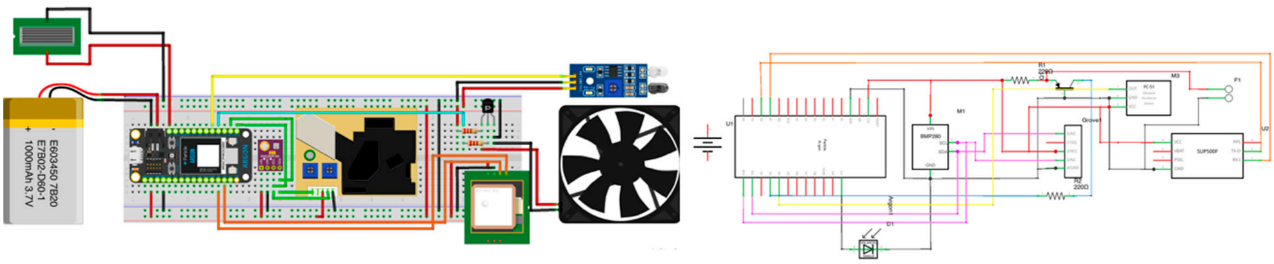

Figure 4. Left: the breadboard diagram. **Right**: the schematics.

3.3. The Hola Hoop

Generally speaking, since the 1980s and 1990s people have become more consumed with work, resulting in sub-health status. Young people are health-conscious but lack healthy behaviors as well as initiative and self-management awareness, and they do not have enough motivation to encourage them to exercise regularly. Time and space limit traditional sports, making it difficult to meet the needs of young people who want to maximize use of fragmented time. The Hola Hoop is a smart wearable device designed by Yizhou Fan, Zhenyu Jiang, Jiatai Li, and Ning Sun, who were contestants in 2019, for white-collar office workers who are often sedentary and engage in insufficient physical activity based on IoT technology. It obviates space constraints and achieves fragmented sports needs for young sedentary users. As shown in Figure 5, sensors connected to an open-source hardware obtain data on user actions. The shell is a detachable clasp structure for product modularization. The hardware configuration includes the MPU6050 six-axis sensor with built-in three-axis acceleration and a three-axis angular velocity device. By integrating the Kalman Filter, Hola Hoop analyzes Euler angles and quaternions. The Arduino and IO expansion board accepts a six-axis signal from the sensor, the signal is parsed, and four relay control switches are closed. The closure of the relay switches controls the vibration of the motor.

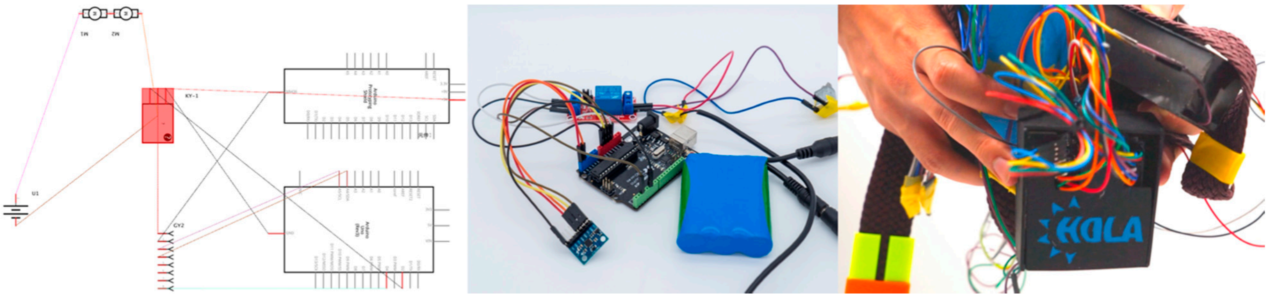

Figure 5. Left: the schematics. **Middle**: the sensors and a battery connected to the Arduino and IO expansion board. **Right**: the low-fidelity prototype.

A usage scenario is as follows (Figure 6): Jiang is a programmer working at an internet company and often works overtime, so he does not have sufficient time to exercise. Jiang's body is of sub-health status. Jiang tries to exercise with various kinds of fitness solutions in his free time, but he cannot control the exercise time, nor find friends to exercise with. One day, a new programmer colleague recommends him the Hola Hoop. Jiang downloads its mobile application, adjusts, and wears it. Following the instructions, he chooses a favorite song and starts a 'rhythmic' fitness mode to play a tangible interaction game [32]. During the game, Jiang feels real-time and haptic feedback accompanying his movements. After completing the game, he uploads and shares his customized rhythms to social media and invites other players to challenge him. He is pleasantly surprised that the Hola Hoop collects his body and movement data through playing games and generates a personalized training plan to help him improve his health status. Jiang and his colleagues enjoy using the Hola Hoop in the office, at home, and when commuting.

Figure 6. The scenario of exercising with Hola Hoop, including various contexts, interactions with the mobile application, and the improvement of health status (e.g., losing weight).

3.4. The Invisible Guardian

Women's safety issues are receiving increasing attention. However, there is little research and design for enabling efficient self-defenses with existing products, e.g., manually operated alarm triggers can be unsuitable in sudden and dangerous contexts. The Invisible Guardian is a smart portable device designed by Yuwei Sun, Yanshuang Zeng, and Yishan Liu, who were contestants in 2019, for young women who fear and worry about crime when walking alone on the streets in cities at night. To ensure women's safety in this context, it monitors threats in real-time and generates an alert automatically when a real danger occurs. There are four main features: (1) judge the safety levels of the surrounding environment, (2) an alert to scare away the criminals, (3) call the police and emergency contacts, and (4) send SMS with real-time GPS information promptly.

The software and hardware engineering design components are shown in Figure 7: (1) a Raspberry Pi, (2) a NVIDIA Jetson Nano development board, (3) a Micro SD Card, (4) an infrared binocular camera, and (5) a GSM/GNSS/GPRS module. The Raspberry Pi, as the control core, uses neural network technology for processing position data and SMS transmission. The prototype applies open pose human posture recognition and infrared distance measurement technologies to analyze distances, posture behaviors, and malicious intents from people behind. When a simulated ringtone of an incoming phone call lasts for twenty seconds, an automatic alarm with loud sound and flashing lights is turned on. To prevent a false alarm, the user needs to stroke the device in time within twenty seconds of the simulated ringtone.

Figure 7. Left: a sketch of the components. **Right**: the schematics.

3.5. The BraVo

Depression is a common mental illness characterized by loss of interest, loss of concentration, guilt, or loss of self-worth, accompanied by problems such as insomnia or appetite disorders [33]. Long-term moderate or severe depression can lead to serious illness and even suicide. The BraVo is a physiological indication system designed by Mengfan Li and Han Xu, who were contestants in 2017, for female college students to manage depression. BraVo adopts the form of a lady's corset, which is as natural as the second skin of a woman. The form provides a natural and relaxed product experience. The prevention of depression is divided into three categories: (1) the prevention of depression in patients with potential depression, (2) the prevention of aggravation in the treatment of depression, (3) the prevention of recurrence after the treatment of depression. The prototype embeds sensor measurement components in the inner layer of the corset. The motherboard of the sensors is hidden in the inner layer. The physiological indicator measurement sensor is arranged on the surface layer adhering to the skin to facilitate accurate data collection. There are three types of sensors: (1) heart rate variability index is measured and calculated by the heart rate detection sensor, (2) sleep index is measured by the heart rate detection sensor combined with a vector sensor, (3) skin electrical index and skin temperature difference index are calculated by skin sensor measurement. This design has been patented as a new utility model by the state intellectual property office of China (ID: ZL201721457774.2).

A usage scenario is as follows (Figure 8): Xiaomei, a senior female student, is now preparing for the national post-graduate entrance examination. She is under high pressure of study. Facing the concerns of her parents and friends, she always shows her optimism. In fact, she could not sleep well every night, fearing that she would fail her examination. After a while, she seems to be not in a good state and her study efficiency decreases. Xiaomei goes back to her hometown to see her mother, who is worried about her mental state. Her mother buys a BraVo for her. Xiaomei returns to school the next Monday but continues to have insomnia at night. One morning, she feels physical pressure. Its mobile application reminds her that her depression index has risen recently, suggesting her to adjust herself through exercise. She follows the BraVo's advice and starts running for a while every night. After a few days, her insomnia eases, her sleep quality improves, and her study efficiency improves as well. The mobile application reminds her that recent physical and emotional changes are better and sends her words of encouragement.

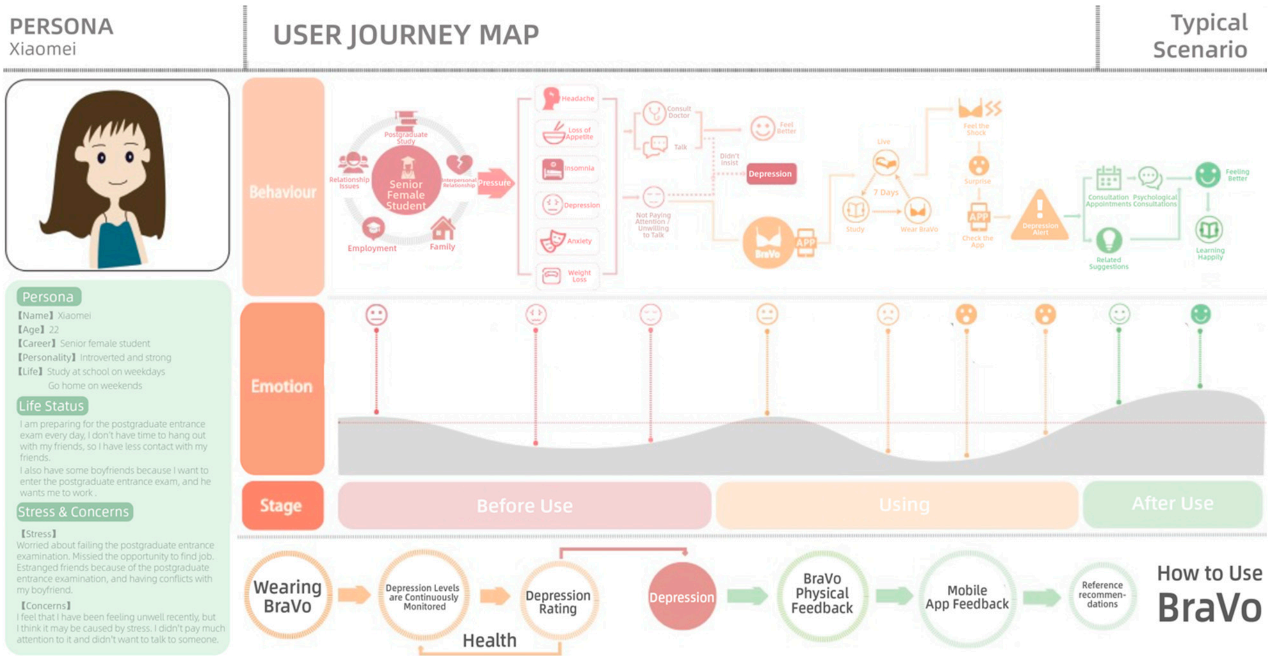

Figure 8. Xiaomei's user journey map with the BraVo.

4. Discussion

Besides participating in the China–U.S. Young Maker Competition and creating experiential prototypes, explorations of establishing a maker innovation center, the integration of research labs, the definition of a novel research framework, and promotion of a new transdisciplinary research track have been undertaken.

4.1. The Establisment of a Maker Innovation Center

At present, a total of twenty-nine universities and institutions have set up the Innovation Center for China–U.S. Youth Exchange to foster a favorable innovation environment. Different from technology-driven and business-driven innovation, established in October 2018, the center at our institute adopts education-driven innovation, making full use of the advantages of university research and integrating social resources. The center covers a gross building area of 1200 square meters, including a lecture hall, a seminar room, and a central office. The space can accommodate over two hundred people at the same time. There are several maker research labs, including an intelligent hardware lab, an HMI lab, a VR lab, a group interaction lab, a usability assessment lab, and a behavioral observation lab. With the aim to train talents with applied and innovative abilities to meet the demands of the development of contemporary society, the center functions as a 'fourth classroom' which links the university and society and introduces real and complicated social professions. Students are deeply immersed in the role of pre-profession and the guidance of maker educators as imagineers and coaches, in which they learn to adapt from a college student into a professional person. The center is dedicated to providing students and teachers with a sound environment for maker innovation, ensuring that students can devote themselves to design and research with full enthusiasm and motivation, forming a shared and equal atmosphere with mutual respect and collaboration.

4.2. The Integration of Research Labs

Among over fifty applied research labs at the center, a human–machine interaction (HMI) lab and an intelligent hardware lab have been designed to train non-engineering students to conduct experiments on future ways of teaching, learning, transporting, and playing. The research team specifically investigates HMI and intelligent hardware in creating new AR, VR, and MR experiences, experiential prototyping solutions, and testing usability. For advanced technology-driven maker projects, the team analyzes data collected from eye-tracking, EEG, electromyograms (EMG), and functional near-infrared brain spectroscopy (fNIRS) devices.

4.3. The 4E Framework

To foster new ways of design thinking [34,35], doing [36], and tinkering, a 4E teaching and learning framework (i.e., empathy, enlightenment, enthusiasm, and exploration) has been invented, adopting innovative research methods and visual teaching toolkits, and guiding students to work in teams for project-based learning. (1) Empathy: to think and feel what other people think and feel. (2) Enlightenment: to motivate, inspire, and guide students to discover and solve real-world problems in a real-world context. (3) Enthusiasm: to ignite and maintain students' passion in iterative thinking, making, and tinkering. (4) Exploration: to translate abstract ideas into down-to-earth practices in open-ended research settings both defining scopes and generating results. To further discuss and implement maker innovation, a REAL (i.e., social responsibility, education innovation, academic excellence, and leader development) framework is now being developed.

4.4. The NeuroDesign

To further promote transdisciplinarity, a new research track called the Leifer NeuroDesign Research Program (neurodesign.stanford.edu, accessed on 11 November 2021) at Stanford University has emerged. Other universities have joined, including the University of Potsdam, Beijing Normal University, and the Tokyo Institute of Technology. This program is a new transdisciplinary initiative between the neurocognitive sciences and psychology and engineering, architecture, computer science, and other disciplines. The program aims to investigate thinking in design, team performance, and practices through approaches from human–computer interaction (HCI), design research, and experimental psychology, and by utilizing neuroscientific instruments. It aims to examine team practices that produce meaningful, innovative, and practical designs [37–40]. Current research investigates design activities and maker innovations from various perspectives, including neuroscience, embodied cognition, phenomenological, Gestalt, and other perspectives.

5. Conclusions, Limitations, and Future Perspectives

In this paper, we have argued that maker innovation shifts paradigms and pushes boundaries, explores major technology trends and engineering design opportunities, and changes ways of interacting with the world. The transdisciplinary engineering design approach is essential for exploring and evolving maker innovation. Several prototypes have been built, each demonstrating contexts of use in everyday life, novel characteristics of user system interactions, and emerging technologies, which could enable, support, and affect new ways of living and working. Through iterative thinking, doing, and tinkering in the research context (i.e., the competition), a co-working makerspace has been established and new knowledge in maker innovation research has been generated.

There are some questions that we have not addressed in this research. It would be interesting to design and assess an innovation and entrepreneurship education framework across elementary schools, middle schools, high schools, and higher education institutions. Such a framework can form four levels of impact: (1) fostering minds, (2) changing behaviors, (3) building communities, and (4) improving structures. It would also be interesting to investigate the 'Double Reduction' policy for young students in China, i.e., a reduction in homework and in time spent in extra-curricular classes or after-school private tutoring (en.moe.gov.cn/news/press_releases, accessed on 12 December 2021). This policy gives space and encourages the research team to transdisciplinarily teach engineering design to young students.

The next step of our research is to further conduct prototyping studies through innovation and entrepreneurship research, in which the new knowledge gained is specified, implemented, and tested. The research team will conduct two major maker innovation research schemes in 2022–2024. (1) K-12 empathy design tinkering in a Chinese context. How can K-12 students learn, practice, and apply design thinking in everyday life? This study investigates learnability, creativity, and team collaboration through cognitive fNIRS and magnetic resonance imaging (MRI) experiments. (2) Social inclusion for the elderly with mild cognitive impairment (MCI) in a digitalized world. How can we include and engage the elderly with MCI in the digitalized world? This study investigates cognition of pathological aging in everyday interactions with digital devices and NeuroDesign and inclusive design solutions.

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