USING THE STEAM x D FRAMEWORK FOR TRANSDISCIPLINARY DESIGN TRAINING OF UNIVERSITY STUDENTS THROUGH THE FRESHMORE ASIAN CO-CURRICULUM TRIP (FACT) PROGRAMME

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ABSTRACT
In this work, we extended the *STEAMxD* (STEAM = Science, Technology, Engineering, Arts and Mathematics, and D = Design Thinking) framework to a student transdisciplinary product design training outside the conventional classroom context. The student training was carried out through an international institutional collaboration between universities in Vietnam, Brunei, and Singapore, termed the Freshmore Asian Co-curriculum Trip (FACT) developed for first-year students at the Singapore University of Technology and Design (SUTD). In the collaboration with *Fulbright University Vietnam (FUV),* 30 first-year SUTD students and 18 2nd-, 3rd, and 4th-year FUV students participated in a 5-day product design programme with emphasis on sustainability of the textile industry (e.g., clothing re-use and shoe design and fabrication), while in the collaboration with the *Universiti Brunei Darussalam (UBD),* 37 first-year students from the *Singapore University of Technology and Design (SUTD)* participated in a 5-day product design programme focused on conservation and sustainability. In both programmes, the double diamond design thinking framework (Discovery, Define, Develop, Deliver) was applied while students received "just-in-time" training in various disciplines, such as the socio-cultural-historical context, micro-design innovation, sight visits, sustainability design, idea generation, prototyping, and communication. At the end of the 5-day programme student teams of 4-5 students showcased their prototypes/ideas to a panel of expert judges from academia and industry to receive feedback. In general, some prototypes raised the interest of industry partners due to their creative solutions, while the programme student survey feedback showed high levels of student engagement, enhanced awareness of *Design Thinking, Sustainable Design, Transdisciplinary Design, and the Socio-Historical-Cultural* context when addressing real-life problems. On one hand, the *STEAMxD* framework is suitable for transdisciplinary training, an educational requirement in the 21st century, while on the other hand, the students participating found the 5-day international transdisciplinary product design programme a useful, enriching, and unique design experience. This work will benefit those interested in transdisciplinary design education, product design, sustainable design education, and those interested in applying a time-tested framework for creating successful educational experiences.

Keywords: STEAMxD, product design, transdisciplinary education, sustainable design, FACT trip

1 TRANSDISCIPLINARY DESIGN EDUCATION AND ITS OBSTACLES
In an innovation-based economy, creativity plays a pivotal role in the education sector, therefore, in an effort to foster creativity, design thinking has been applied, since it provides a pathway to solve real-life problems in a collaborative manner. As the complexity of real-life problems increases, a transdisciplinary approach has been proposed as a training opportunity for the 21st century. Although there are differences in the definition of transdisciplinary education [1, 2], here we address difficulties in creating training programmes at the university level. In recent years, we have proposed the *STEAMxD* framework as an approach to train pre- and university students with significant success within a university setting [3, 4]. Hence, we wanted to know if such an approach can be successfully applied in

an international setting. With *STEAMxD* methodology in mind we posed the following question: specifically, can students work out practical solutions to real-life problems in an international environment, working with international students, in an unfamiliar context, in collaboration with industry partners at the host institution, to address real-life scenarios? For this end, we used three criteria: (1) The ability to set up a 5-day *STEAMxD* programme internationally, (2) industry partner feedback on prototypes, and (3) student self-efficacy surveys. There are several complications in training students in transdisciplinary education [5-15]. However, there are currently two main obstacles for university students to be trained in transdisciplinary design: (1) setting up a multidisciplinary faculty team to create and execute a transdisciplinary project, and (2) allowing students to address a real-life problem in an unfamiliar out-of-classroom context, given current university organisational structure. In Table 1, adopted from references [1, 2] we list the main characteristics of the *STEAMxD* framework, and the current general traits associated with transdisciplinary design, with a significant overlap between them, suggesting that the framework can be used as a transdisciplinary training programme.

Table 1. The STEAMxD framework falls under the definition of transdisciplinary design

Index	*STEAM x D* framework	Transdisciplinary design
1	The project is larger than its disciplinary parts	Maximum degree of discipline overlap
2	Design thinking driven	Integration of design thinking with other disciplines
3	Design narrative	Integrates design thoughts
4	Emphasis on the socio-cultural-historical context of the design	Stakeholders help identify and conceptualise the problem
5	Applies real-life problems	Applies to highly complex real-life problems
6	Multidisciplinary team	Stakeholders and social actors participate
7	Just-in time learning	Mixed and pragmatic methodological approach
8	Prompt feedback	
9	Teamwork and collaboration	
10	Design challenge	Considers emerging problem in the future
11	Design competencies mapping	Long term evaluation of the project
12	Design rubrics and metrics	
13	Unfamiliar and/or international setting	
14	Sustainability as a layer of analysis	

2 ADDRESSING THE TEXTILE INDUSTRY IN VIETNAM

The 5-day long *STEAMxD* workshop operated under the *Sustainability* theme and was sponsored by the Freshmore Asian Co-Curriculum Trip (FACT) wherein students are hosted by a partner university in the Asian region, usually for 5-7 days. Moreover, two industry partners, **Passii,** a second-hand clothing consignment startup, and **Biti's**, a 40-year-old Vietnamese footwear company, were invited to participate by providing current, real-life challenges, which were turned into design opportunities by the 48 students working in 8 teams of 6 members from both universities. The students were supervised on a continuous basis by 2 faculty members (1 SUTD, 1 FUV), 4 student helpers (2 SUTD, 2 FUV), and 1 administrative staff member (FUV). Additionally, guidance was provided by visiting faculty teaching 1 or 2 sessions in the programme, such as the Socio-historical-cultural context, Figma training, and by industry partners. SUTD students were 1st-year students with various interests (product development, information technology, architecture, systems design) while FUV students were in years 2-4 from various disciplines (computer science, human-centred engineering, economics, social science, arts and media).

2.1 The challenge

The industry partners provided the following refined problem statements to the students, who were expected to provide practical solutions within a short timeframe.

- **Biti's:** *Sustainable design: How to support the design process of Biti's shoes to reduce material waste and carbon footprint throughout the product lifecycle.*

- **Passii:** *Optimising the data entry process: How to accelerate itemised data entry using image capture to extract and output a detailed data table. Attributes should include brand, material, estimated retail price, colour, and more. The goal is to develop a module that enhances speed and accuracy.*

2.2 The *STEAMxD* framework

The programme as shown in Table 2 was an adaptation of a previously described *STEAMxD* framework [3, 4], which is design thinking driven and emphasises the socio-cultural-historical context as a requirement for delivering successful solutions to real-life problems. Furthermore, the programme afforded onsite visits to better contextualise the challenges, with students re-framing the real-life problems on day 3. Subsequently, students, focused on prototyping, python coding, and product life cycle analysis.

Table 2. Agenda of the five-day programme

Day	Morning Session	Afternoon Session
1	[**Discovery]** Ice breaker, design brief, and social-context on Fashion market/ textile industry.	**[Discovery]** Design thinking session (Micro-DI on textile industry), and problem briefing session by Passii industry patner.
2	**[Discovery]** Field trip to Biti's factory and sharing on problem statement.	**[Discovery]** Field trip to visit the Passii Stations (where they have their consignment clothes sold in their partner cafes).
3	[**Define]** Reframe the challenge. [**Develop]** Idea generation session.	**[Develop]** Figma training session. **[Develop]** Prototyping, programming, sustainablity.
4	**[Develop]** Prototyping, programming, sustainability.	**[Develop]** Prototyping, programming, sustainablity.
5	**[Develop]** Final prototyping, programming, sustainability.	**[Delivery]** Design challenge storyboard presentation.

2.3 The process and outcome

3 teams selected **Biti's** challenge while 5 teams chose **Passii's** challenge. Equipped by the *STEAMxD* framework, guided by the double diamond model, the teams reframed the challenge, generated ideas, developed and tested the prototypes as seen in Figure 1. Figure 1(A-C) showcases the proposed product designs for **Biti's** challenge. All 3 teams adopted a modular design approach for a new shoe model, focusing on different aspects of shoe design to address sustainability concerns. The shoe designs emphasise ease of disassembly, allowing components made of different materials to be effortlessly separated, thereby encouraging consumers to recycle. Additionally, the modular structure enables easy customisation, repair, and replacement of parts, extending the lifespan of the shoes and promoting sustainable consumption. Moreover, in the designs shown in Figure 1A and 1C, special joining mechanisms were introduced to minimise the use of adhesives and glue, rendering the products more environmentally friendly.

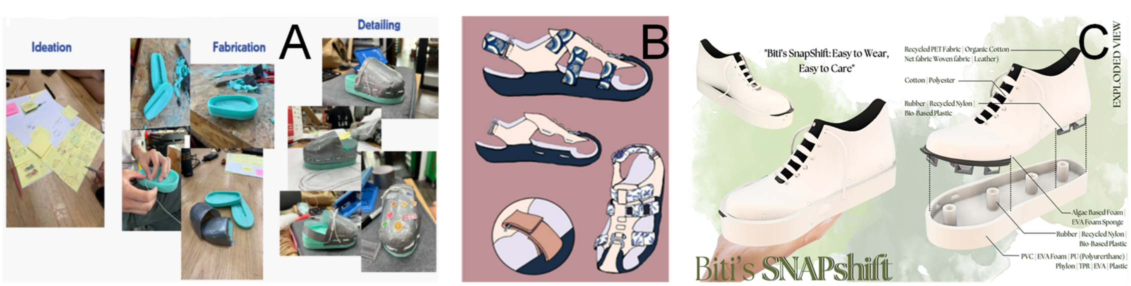

*Figure 1. Modular and personalised proposed solutions to **Biti's** shoe design challenge*

Finally, sustainable design was addressed both through product innovation, as seen in **Biti's** modular shoe designs, and through process optimisation, such as **Passii's** technology-driven approach to recycling and resale of garments. Figure 2(A-C) displays 3 solutions for **Passii’s** challenge. Notably, all teams proposed integrating advanced technologies such as computer vision and artificial intelligence (AI) to automate key stages of workflow, including inspection, sorting, data collection, pricing, and listing second-hand clothing on a website. Several teams went a step further by developing physical prototypes alongside functional software tools to demonstrate their solutions.

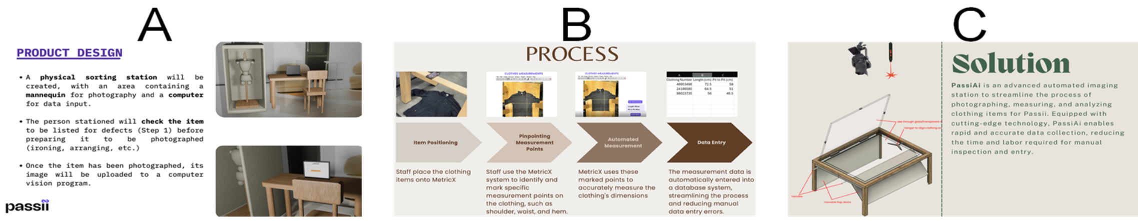

*Figure 2. Proposed solutions to **Passii’s** optimised data entry process. Note the design flow of design, process, and solution*

3 ADDRESSING CONSERVATION AND SUSTAINABLE DESIGN

This programme was carried for 2 consecutive years, 2023 and 2024, where there were 4 and 6 teams, respectively, of 4 students, supervised on a continuous basis by 1 faculty from STUD and 2 faculty members from UBD, 1 student helper from SUTD, and 5 student helpers from UBD. SUTD participants were 1st-year students, who have not chosen a major yet, but expressed interests in product development, information technology, architecture, and systems design. The highlight of the programme was an onsite visit to the Kuala Belalong Field Study Centre (KBFSC) located at the Temburong national park, Brunei, which acted as our “industry partner.” KBFSC sits on a riverbank, surrounded by a tropical forest, reached and supplied upstream through river boats, where electricity is not available at night, and there is no mobile signal, providing to the students an unforgettable and enriching experience.

3.1 The challenge

Students were asked to identify areas of improvement in transportation, logistics, energy, sanitation, building materials, communication, waste management, and trails optimisation at KBFSC. For this end, the students were able to conceptualise the challenge, interview stakeholders, and observe first-hand the site of interest, an opportunity that cannot be had in a university setting.

3.2 The process and outcome

Given the design brief, student teams addressed a set of real-life challenges observed during their visit and while interviewing/interacting with stakeholder, such as staff and research personnel, at KBFSC. These challenges were: (1) robustness of energy systems, (2) solar energy, (3) sustainable river boat transportation, (4) and delivery of food and medical supplies to KBFSC. We highlight one potential solution, which was conceived after the team made the field profiling measurements in day 3. The *Transcend MK I*, shown in Figure 3, seeks to minimise human errors in the field profiling measurements, by equipping the device with a protractor, a compass, and a lever to replace the human eye alignment in the procedure to ensure a more precise measurement.

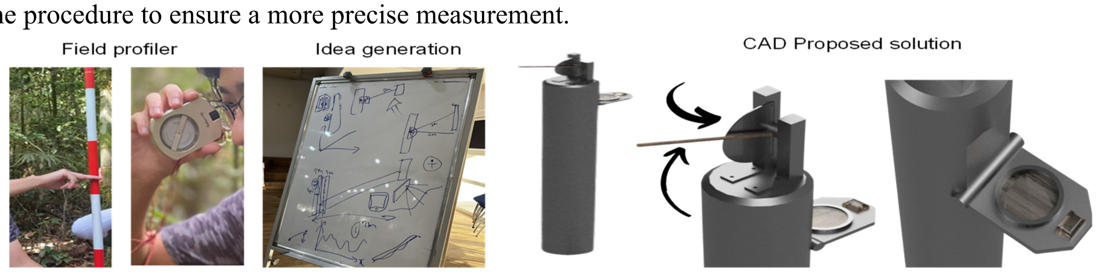

Figure 3. Proposed solution for optimising measurement precision during a field profiling exercise

4 SUMMARIES

4.1 Lessons from successfully applying the *STEAMxD* framework internationally

There are 6 major reflections on applying the *STEAMxD* framework. (1) The onsite visits to ***Biti’s*** factory, ***Passii’s*** stations and KBFSC provided valuable cultural experiences and onsite observations to conceptualise the real-life challenges in a superior manner. In addition, these onsite visits strengthened team bonding, enhancing collaboration in the subsequent project phases. (2) It is highly recommended to have more than one industry partner, allowing student teams to select the most suitable challenge. (3) Industry partner engagement is crucial to the success of the programme. For instance, (i) their interaction with student teams provided a clear understanding of the core operations and goals of the enterprises, (ii) by providing timely feedback to student team questions, and (iii) by being involved in their final prototypes' evaluation as experts in an assessment panel. (4) A best standard practice is to have an organising member (staff or faculty) act as a communication liaison between industry partners and student teams. This person collects student inquiries in a chat, summarise them, and forward the questions to the partners once a day, then relay the responses back to student team. (5) There are a few challenges faced during the implementation of the programme. (i) Crafting the daily 5-day programme between collaborating teams from 2 universities due to non-familiarity with the *STEAMxD* framework, lack of available expertise needed to either transfer technical skills during a session or form a judging panel, and (ii) lack of logistics support. (6) We observed major differences between Brunei, wherein students had ready access to stakeholders, but no makers space, and in Vietnam, wherein students received their technical training in a maker's space but had limited access to stakeholders.

4.2 Importance of transdisciplinary education

Given the complexity of today's problems, early training for young students in transdisciplinary education is pivotal under the motivation of practical hands-on experience (experiential learning), and a requirement for any head start in the labour market. At SUTD, early transdisciplinary training starts in the first year and ends in the final year through the Capstone programme. *STEAMxD* as a framework offers the advantage of being a tested platform since it has already been adapted by the ministry of Education (MOE Singapore) to train pre-university students. The desired characteristics of the framework can be found in Table 1; however, the following 4 features are paramount for its implementation: (1) Teamwork and collaboration to ensure strong team dynamics, (2) "just-in-time" technical training to deliver needed expertise, (3) timely feedback from all stakeholders, such as faculty, student helpers, staff, and industry partners, and (4) a strong logistics support team.

4.3 Industry partners feedback on prototypes

Both industry partners in Vietnam expressed significant benefits from participating in the programme. For instance, one of **Passii's** founders, who came from a social entrepreneurship background, had limited exposure to technology and was impressed by how relatively simple technological solutions, such as automated photography and computer-aided data entry, could save time and reduce workflow errors for their staff. **Biti's** representatives selected the design shown in Figure 1C (*Snapshift*) as a viable, ready-to-market solution, and even offered summer internships to the team members to further develop the prototype. Meanwhile, the staff at KBFSC in Brunei requested an extended collaboration to produce the *Transcend MKI* solution into a minimum viable prototype (MVP) and to have it field tested the following year.

4.4 Student self-efficacy

We note that the students found KBFSC, and **Passii** and **Biti's** on-site visits tremendously useful to better conceptualise the design challenge, data not shown. Figure 4 shows that students determined that the 5-day long transdisciplinary product design training improved their understanding in design thinking, sustainability, and sustainable design.

Taken together, the benefits of transdisciplinary product design training of university students by applying the *STEAMxD* framework as a method outside the university setting and at an international level, in collaboration with industry partners, and by providing "just-in-time" training, has shown to be a successful strategy to overcome obstacles traditionally associated with transdisciplinary training [1, 2, 5, 7, 8, 11]. This is in total contrast with the inability to set up transdisciplinary training at most universities, which suffer from rigid, silo-like organisational structures (faculties, colleges, schools), failing to communicate with one another, and hence are not capable of collaborating to put together a programme.

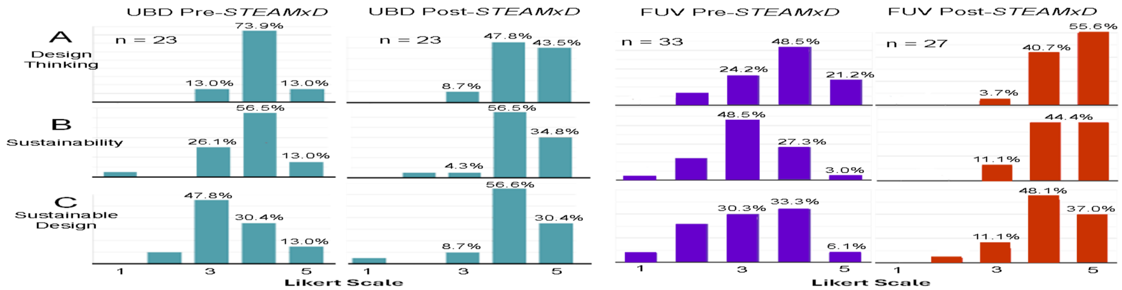

Figure 4. Student response to pre- and post-STEAMxD training in UBD (left) and FUV (right) on A. design thinking, B. sustainability, and C. sustainability design. 1 = not familiar, 5 = very familiar

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