Fostering sustainability capabilities through experience: A case study on virtual mobility in STEM

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Abstract

For a 21st century facing cascading crises, including global pandemics, climate change, and social and economic disruption, education is more critical than ever. Universities, and consequently their curricula, have a responsibility to prepare all students and graduates to respond to and live within a disrupted, complex, and uncertain future. One way of preparing students to think and address complex global challenges is through international learning experiences. However, the global pandemic triggered an unforeseen disruption to student mobility and the acceleration of online learning environments, such as virtual mobility programs. To date there has been little exploration of how virtual mobility programs can be designed for science and their ability to foster sustainability capabilities within the discipline. This paper reports on the design (its curriculum and pedagogy) of an experiential virtual mobility program, designed and delivered during the pandemic. It illustrates an innovative, co-created, STEM-focused case study whereby learning focused on varied approaches to agricultural challenges and practices. Through the perspective of student participants, key education for sustainability capabilities of sustainability thinking, collaboration, affective learning, critical reflection, and interdisciplinary knowledge were analysed as themes and are discussed in relation to how these capabilities were shaped by the program design. We share this discussion to support and expand the use of further meaningful virtual experiences to foster sustainability capabilities in an international (online) setting by other University educators.

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Introduction

As our current society faces cascading crises, including global pandemics, climate change impacts, and social and economic disruption, the importance of sustainability education is more critical than ever (Ayers, 2020; Salazar & Dollin, 2021). Educational institutions and, consequently, their curricula have acknowledged the need to prepare all students and graduates across diverse disciplines to respond to and live within a disrupted, complex, and uncertain future. This necessitates the development of sustainability capabilities that allow students to critically envision a more sustainable and equitable future (Dollin et al., 2022).

In working to build students' sustainability capabilities, many higher educational institutions are reimagining the way they are providing transformative curriculum and learning experiences for their students (Holdsworth & Thomas, 2021; Tilbury, 2004; UNSECO, 2021). Among the innovative strategies employed, international learning experiences, namely outbound mobility experiences (OMEs), are an ideal experiential tool to foster sustainability outcomes. However, the global pandemic triggered an unforeseen disruption to outbound mobility – one that is not isolated – and the acceleration of online learning environments, notably virtual mobility programs.

This case study highlights a STEM-focused, co-created virtual mobility experience (VME) and discusses how sustainability capabilities were shaped by the program design. Designed and delivered during the pandemic, the short-term VME was an opportunity to bring together Australian and Indian educators, academics, and students from different disciplinary backgrounds to discuss, explore and research agricultural challenges and practices. It draws on the experiences of a small group of undergraduate science students from an Australian university who actively participated in the online program.

Literature Review

Internationalising Sustainability Education Through Student Mobility

Introduced over fifty years ago, the concept of sustainable development achieved universal significance, with education playing a critical role. Currently, attention is being placed on the United Nations 2030 Agenda for Sustainable Development - encompassing the 17 Sustainable Development Goals (SDGs) - as an aspirational blueprint to transform our world, particularly now as we recover from a global COVID-19 pandemic. Universities are actively translating this global framework into their practices and programs, accepting the responsibility of equipping students and graduates with the capabilities needed to address complex global challenges (Ayers, 2020; Dollin et al., 2022; Holdsworth & Thomas, 2021). Ending poverty, fighting inequality and injustice, improving health, and addressing climate change are just a few of the global challenges that graduates will face, all of which are reflected in the 2030 Agenda.

The current Education for Sustainable Development (ESD for 2030) framework - situated under SDG 4 Quality Education - explicitly aims to "ensure that all learners acquire the knowledge and skills needed to promote sustainable development" (United Nations, 2022). ESD, or Education for Sustainability (EfS) as it is known in Australia, is a pedagogical approach that encompasses a wide range of capabilities. Capabilities such as sustainability thinking, collaboration, affective learning, critical reflection, and interdisciplinary knowledge are critical in envisioning a better

future (Thomas & Day, 2014). They go beyond competencies (or skills) and instead expect that an individual will develop a "critically reflexive approach to both personal and new forms of professional practice" (Holdsworth & Thomas, 2021, p. 1469). In practice, this would enable students to advocate for social and environmental justice, fostering their understanding and respect for people and things (i.e. the human and more-than-human world). It also equips them to think creatively in a rapidly changing world (Holdsworth & Thomas, 2021; Scharoun, 2015; Thomas & Daly, 2014). However, developing these sustainability capabilities requires pedagogical approaches that enable students to engage in active, hands-on learning engaging with real-world challenges and contexts (Stibbe, 2011).

Outbound mobility experiences (OMEs) involve exposing and immersing university students in diverse cultural, environmental, and economic contexts. The term OMEs encompasses international learning activities such as work (internships or placements), research, faculty-led study tours, volunteering or community service, whereby students "remain enrolled at their home institution while travelling abroad for a component of their home degree" (Potts, 2015, p. 4). OMEs, when carefully designed, are an ideal learning environment to prepare and transform students' ways of thinking and engaging with the world and its complexities (Bunch et al., 2013; Garibay, 2015). They create a unique learning environment (and space for innovative curriculum design) whereby students can engage with tangible contexts, collaborate with others, and develop new perspectives, appreciations and understandings of sustainability challenges, practices, and solutions (Ayers, 2020; Hoyos et al., 2015; Potts, 2015). Several studies have looked at the impact of short-term OMEs on student sustainability knowledge and values (Bell et al., 2021; Tarrant & Sessions, 2008; Zhang & Gibson, 2021). For example, Bell et al. (2016), who delivered an experiential OME to several destinations in the Pacific region, found that students developed an appreciation for nature, new perspectives of cultural and social differences and were exposed to sustainability practices in a post-trip survey. Their findings also indicated that as a result of the experience, students had a "new awareness of different types of contemporary sustainability issues" (Bell et al., 2016, p. 399), which led to a desire to make change and take action in their home country. The development of sustainability capabilities is vital in preparing students to address complex environmental and social challenges and is acutely necessary in the sciences.

Engaging undergraduate science, technology, engineering, and mathematics (STEM) students in immersive experiences, like OMEs, offers a wide range of well-researched benefits - persistence in the discipline, identification with the discipline, increased interest in STEM careers, and increased inclusivity of underrepresented groups (Adkins-Jablonsky et al., 2020; Garibay, 2015; Guest et al., 2006; Hardiman et al., 2022; Sanders & Hirsh, 2014). OMEs have the potential to be intentionally designed to foster undergraduate STEM students' critical thinking and creative capabilities - fundamental to EfS - by deeply exploring global challenges and solutions facing modern scientists through the process of scientific inquiry (Garibay, 2015; Sanders & Hirsh, 2014; Scharoun, 2015; Tran & Vu, 2018; Tran et al., 2021). Discipline-specific and sustainability capabilities can be enhanced by exposing STEM students to "substantial and meaningful real-world experience with another culture" (Matherly, 2004, p. 9; Murphy et al., 2019) and different perspectives including environmental, social and political (Holdsworth & Thomas, 2021; Lozano et al., 2012). For instance, the design of research-based OMEs can introduce "social relevance into the coursework", which in turn leads to an "increase sense of civic engagement and

appreciation" (Adkins-Jablonsky et al., 2020, p. 2). Myers et al. (2005) also found that their short-term OME program enabled students to achieve cross-cultural, personal and professional transformation. They attributed this transformation to the design of their interdisciplinary STEM program, which was developed with a service-learning approach incorporating intensive work-oriented activities situated within rural communities. Arguably OMEs are a rich opportunity for STEM curriculum and pedagogy (Wubbels & Girgus, 1997), yet they remain significantly underutilised within the discipline.

The recent COVID-19 pandemic has significantly restricted international travel and disrupted traditional student mobility programs, forcing the pausing of many existing programs. An acceleration of a variety of online programs, such as virtual mobility alternatives, by the higher education sector has taken shape to fill this gap. Virtual mobility experiences (VMEs), also known as virtual exchange or collaborative online international learning, involve the digital delivery of experiences through technology to facilitate intercultural learning and collaboration. These programs can serve as substitutes for in-country experiences or enhance them (Davidson et al., 2020; Villar-Onrubia & Rajpal, 2016; Vriens et al., 2010). Broadly, these online learning experiences have been shown to facilitate an intercultural experience without travel (Buchmüller et al., 2021); develop university students' capabilities in digital literacy, critical thinking, and intercultural communication (Normand-Marconnet et al., 2022); and enhance self-confidence in applying their capabilities to real-world situations (Azeiteiro et al., 2015). They have also been utilised to deliver EfS in an online environment. Nevertheless, there has been little exploration of how virtual mobility programs can be designed (or redesigned) for science (Hardiman et al., 2022), and even less has been studied regarding their ability to foster sustainability capabilities within the discipline. This paper seeks to explore how the design of the program shaped the development of sustainability capabilities amongst Australian undergraduate science students, presenting a case study for consideration.

Case Study: The Australia-India Virtual Program

Located in Uttar Pradesh, India, the Centre for Environment Education North (CEE) has a long-standing partnership with Western Sydney University (WSU), formed through a global ESD network (namely, Regional Centres of Expertise on Education for Sustainable Development). In the past, both institutions collaborated to deliver two in-country OMEs (in 2018 and 2019), focused on the SDGs in relation to clean water and health. This case study focuses on the Australian-India Virtual Program, which was designed to offer a new virtual mobility experience during the COVID-19 pandemic.

Four facilitators from WSU - authors of this case study - worked together with three Indian facilitators from CEE North. Over a span of six months, they collaborated to co-design, co-develop, co-deliver and co-credential this VME (Barrie & Pizzica, 2019). This collaborative effort included organising program activities, shaping learning objectives, liaising with local experts, providing feedback and care to students, reviewing student work, and awarding digital credentials. Additionally, the facilitators also provided and monitored the e-learning platform and the coordination of informal online social and cultural activities.

Delivered online in July – August 2022, the 8-week VME program engaged 31 STEM students (eight Australian and 23 Indian). The program consisted of formal bi-weekly lectures from

Australian and Indian experts on local agricultural-related topics. It also included formal and informal cultural and social peer-to-peer activities, a bilateral collaborative group research project with weekly scaffolded tasks and reflective debriefs, self-guided e-learning content covering sustainability, agriculture, and the SDGs, as well as reflective journaling.

The Australian students were drawn from the hosting university - WSU - and were subject to the eligibility criteria defined by Australia's New Colombo Plan Mobility Project. These criteria included being domestic undergraduates, with the majority aged between 18 - 28 years old. In contrast, the Indian students applied to participate via a nationwide open call from various university and education networks, including the Australia-India Water Centre and the CEE Academy, from all levels of study (undergraduate, honours, postgraduate and higher degree research). A total of 18 different Indian universities were represented from across India. New Colombo Plan funding supported the online delivery with educational partners in India, subsidising the participation of all students.

Facilitators ensured that weekly expectations were clear, following up with a weekly summary and Zoom recordings via the e-learning platform, ensuring flexibility to aid student participation. At the conclusion of the virtual program, eligible participating students received a co-branded certificate and digital badge in recognition of their achievement (assessed on attendance and submission of work). Each Australian student received academic credit towards their degree program, with their portfolio of work completed during the program serving as an alternative assessment within existing subjects.

Program Objectives and Design (Pedagogy and Curriculum)

The Australian-India Virtual Program provided students with a unique opportunity to delve into the complex and multifaceted world of agriculture through a series of well-designed experiential activities. Agricultural issues provided a rich context for investigating the interaction of social and natural domains while focusing on practical challenges faced by real people (Roberts et al., 2018). The program's primary objective was to enable students to develop a deeper understanding and appreciation of sustainability as it relates to agricultural practices in different contexts. It also aimed to encourage students to critically investigate agricultural challenges and practices related to poverty, hunger, livelihoods, gender, culture, biodiversity, water, and climate change, within the framework of the SDGs. To meet these desired objectives, the program's design required a pedagogy that challenged students to "participate actively, thinking critically and reflect" (Holdsworth & Thomas, 2021, p. 1478). Active, online experiential learning approaches intertwined with intercultural collaboration and dialogue were employed (Ash & Clayton, 2009; Davidson et al., 2020; Rayner et al., 2013; Vriens et al., 2010). Learning activities included collaborative research projects, social and cultural activities and reflective debriefs.

Students collaborated in bilateral, interdisciplinary research teams, each composed of 4-5 students, with a mixture of Australian and Indian students. Scaffolded research projects were shaped by the facilitators to allow for independent research through predefined weekly tasks, guiding students to respond to broad tasks and questions situated in a real-world context (Willison & O'Regan, 2007). Students collectively selected an agricultural product to research that was relevant to both countries in its production and consumption. Using the INSPECT Model (Bawden & Packham, 1993) as an inquiry framework, students conducted comparative studies on their

chosen agricultural product. The INSPECT Model was a lens to explore agriculture from various transdisciplinary perspectives and influences, including natural, social, political, economic, cultural, and technological aspects. The student teams were engaged in four tasks, culminating in a video presentation, written brief, and group reflection on their comparative findings, which linked to the SDGs. During each weekly Zoom session, time was allocated for students to respond to these tasks. Additionally, students self-organised and managed their projects, completing activities and meetings outside of class through alternative, self-nominated forms of communication, such as WhatsApp.

Student socialisation and collaboration were supported through online intercultural activities (Azeiteiro et al., 2015; Scharoun, 2015) which aimed to foster sustainability outcomes, cross-cultural dialogue, diverse perspectives of science, and build peer networks. Students engaged in live performances, including a traditional Indian 'Bhavai' folk dance depicting water scarcity, climate impacts, gender, and values. They responded to scheduled bi-weekly online discussion posts, including sharing traditional or personal recipes and showcasing local destinations on their bucket list. They interacted through ice-breakers and games during the weekly Zoom session, which included a student talent show where students shared wildlife photography, poetry and music.

Student reflection was aided via verbal debriefs and written responses. Feedback debriefs were planned at various stages of the program (Winchester-Seeto & Rowe, 2019). This included group discussion on their research projects, individual online polling to unpack specific elements of the activities, breakout sessions mixing research teams of students to provide their insights into the others' research, as well as self-led reflective journaling. Feedback debriefs at the end of each live Zoom session provided opportunities for students to discuss, share and reflect on their research insights and learning with the facilitators and the larger class. Additionally, an electronic learning journal was utilised with weekly templates and included free space to record their observations, research, and notes, as well as prompt reflective questions. These prompts were designed to assist students in reflecting on their learning experience, research progress, scientific endeavours, and capability development.

Method

The aim of this case study is to interpret and explore student participants' subjective experiences of the described VME and to explore how the designed program shaped their sustainability capabilities. A qualitative constructivist approach was adopted to understand differing perspectives and comprehend the meanings students ascribe to their lived experiences (Creswell & Plano Clark, 2018; Creswell & Poth, 2018). The study is grounded in the concept of Education for Sustainability (EfS) and the key capabilities it promotes, including sustainability thinking, collaboration, affective learning, critical reflection, and interdisciplinary knowledge, as proposed by Thomas and Day (2014).

Data was collected from two student focus groups (five participants total), facilitated by the lead author who conducted the focus groups and corrected the transcribed recordings. The researchers used reflexive thematic analysis to generate themes, acknowledging their active roles in the knowledge production and interpretation of meaning needed to generate the themes (Braun & Clarke, 2019; 2022).

Participants and Data Collection

Students enrolled in the Australia-India Virtual Program were invited to participate in this study by the primary researcher (lead author). Due to time constraints, ethical approval for interviews with Indian students could not be obtained, limiting our focus to the perspectives of Australian students. From the Australian students enrolled, five consented to participate. These participants were domestic undergraduate science students across four disciplinary areas studying at the same Australian university (Table 1). Pseudonyms were used to de-identify participants.

Student participants willingly attended an online focus group session, held three weeks after the virtual program concluded, led by the primary researcher. The researchers' questions focussed on students' overall experience, their research projects, and their future career orientations. Two focus groups were held to account for student availability, each lasting 90 minutes. The audio was digitally recorded and transcribed.

Table 1

Study participants

Pseudonym	Gender	Field of study (degree majors)	Year Level
Chloe	Female	Animal Science	3rd year *
Olivia	Female	Environmental Health	3rd year *
Robert	Male	Animal Science	2nd year
Sarah	Female	Environmental Science	2nd year
Will	Male	Zoology and Animal Science (Dual Degree)	3rd year

Note: Students in their final year of undergraduate study are emphasised with an asterisk (*).

Data Analysis

Each author initially independently reviewed the transcripts. During their preliminary analysis, each took note of illustrative instances of students describing sustainability learning and capabilities. These were later shared and discussed as a group to create early codes and themes, looking for areas of commonality between researchers (Braun & Clark, 2019). The authors also discussed and acknowledged our personal values and disciplinary reflexivity (Braun & Clark, 2022) in shaping the knowledge produced.

The preliminary findings were then manually merged by the primary researcher. To further refine the themes, the conceptual framework of EfS capabilities, including sustainability thinking, collaboration, affective learning, critical reflection, and interdisciplinary knowledge (Thomas & Day, 2014), was applied. Ongoing discussion amongst the authors related to how the data and the emerging themes fit with the design of the VME and the literature. This process led to three main themes - two that relate to fostering sustainability capabilities and one that unpacks the

experience further. Despite the small scale of this case study, the data provided valuable and rich insight into the student's experiences of their learning and development, as well as the overall virtual mobility experience design.

Results

Overall, the student perspectives illustrated the positive impact the VME design had on fostering sustainability capabilities, particularly with the appreciation of the distinctions between Australia and India. This was particularly evident in the students' reported experiences of engaging with contrasting agricultural practices, shared environmental values and intercultural interactions. The findings are discussed and analysed in the context of key EfS capabilities of sustainability thinking, collaboration, affective learning, critical reflection, and interdisciplinary knowledge (Thomas & Day, 2014).

Exploring and Challenging Sustainability Through Global Perspectives of Agricultural Values, Purposes, and Practices

The collaborative research projects (investigated through the INSPECT Model) inspired students to think about alternatives from multiple dimensions of sustainability. Through research, student teams actively explored differences in the values, purposes, and practices of agriculture in both an Australian and Indian context. One student expressed that "different values can really influence how resources are managed" (Will). The INSPECT Model supported the students' capacity to engage with sustainability thinking at varying levels. Some students expressed a more nuanced understanding of particular agricultural practices that challenged their preconceived ideas:

> I guess the idea that technology makes the [dairy] industry better and more efficient… it just doesn't hold true everywhere and all of the time. (Sarah)

> I want[ed] to have a better understanding of intrinsic and extrinsic values of animal and agricultural beliefs in different countries… our different approaches to even how animals are used and why they should be used, and the different reasons they are used. And more importantly, I guess how sacred they are to some people in comparison to us [Australians]. (Robert)

Another student elaborated further on their perceptions of a deeper connection to land, livelihoods and the food that is grown in Indian culture, which led to a more critical comparison of Australia's values:

> There's harvest festivals around the different farming seasons… post-colonial Australia we don't really have a connection. The traditional [Indian] culture hasn't been taken away, it's still very much thriving in a similar way that it has been for thousands of years, and that's really reflected in their connection to their land and how much significance they put onto the food that they grow, that like keeps the people alive…. it just seems like a more … meaningful connection. (Will)

Other students expressed sustainability thinking by recognising the interconnections between social, environmental, economic, and cultural dimensions and voiced a more holistic understanding of the issues at hand and possible solutions. Engaging with their peers and

conducting research made her reflect and question Australia's practices, envisioning what could be possible:

> I really liked talking about with the [Indian] students the opportunities that hemp can give for sustainability in both countries. Looking at it from a poverty perspective in particular… and how hemp construction products can possibly improve the livelihood for people living in low socioeconomic communities. And also, we've got bushfire issues over here in Australia as well, so the hemp product I know is quite fire resistant. Lots of little things to do with the hemp that I didn't know of before, and how it does meet the overall SDGs… It just made me think, "Why aren't Australia more well versed in the use of the [hemp] plant, when it could provide us with a lot of sustainable options?" (Olivia)

In comparison, the findings of their research raised more despairing questions than answers for one student. Her critical reflection considers the interconnected nature of sustainability challenges that defy simple solutions. Seemingly impacted by the realisation of the complexity of achieving sustainability, she is left puzzled as to a way forward:

> … when you think about it, like in the long run, all the land destruction and the deforestation that occurs, and even the diseases that some of these animals [sheep] might go through, or they could go through heat stress if they're not taken care of properly, and then the stress on the animal getting sheared and handling… like how sustainable is the farm actually… when you actually look at the process that goes into it… there is so much stuff that is not sustainable and not beneficial by any means to then produce something that they call 'sustainable', just because the fibre [wool] itself is, but the actual process is not... like how can something that someone is paid so little for, be then worth so much to be called sustainable but then it's really not at all. It was a hard question to try and figure out an answer to, and then how to solve that problem. (Chloe)

Fostering Value Sharing and Environmental Stewardship Through Social Connection

The program itself focused on sustainability, and as such, it brought together a group of young individuals who are "passionate ecowarriors… working just as hard in their own country to make it a better place" (Olivia). The concept of environmental stewardship was a commonality shared between the Australian and Indian students, noted by students as a highlight of the program. Expressing their personal interests, attitudes, and motivations (affective learning) towards the environment, in reflection, enhanced the social connection. For some, the benefit of the program was sharing between and across various STEM disciplines that connected them:

> We got to meet people from various backgrounds and degrees. It was really good to have that ability to talk to someone who's in the same area as you, same kind of interests overall, and interested in a very similar topic. (Chloe)

Whereas for others, engaging in informal discussions about broader environmental issues allowed them to foster social connections and build interpersonal relationships to improve collaboration:

> The best discussions we ended up having weren't related to our [agricultural] product at all, it was just engaging in general – conversation about general environmental issues, and then everyone really started to get excited and open up a little bit more. (Olivia)

For one student, these environmental values were a stark contrast to the lack of interest that he often perceives within his community:

> A lot of people place very little value on kind of the natural environment and looking after it, so it was nice to see so much… positive interest from a completely different perspective, when quite often I see a total lack of interest so close to home. (Will)

Drawing upon sustainability thinking concepts of shared responsibility and global citizenship, students describe connecting with others as a "nice human reminder" (Olivia) to see other young people "from another country, from a very different place" (Will) sharing the same personal values through similar lived experiences. These "rare moments of connection" (Will) elicited affective emotional and empathetic responses that shifted the students' views of one another and reinforced a sense of togetherness in the face of global uncertainty.

Collaborating, Learning, and Travelling Online

This virtual mobility experience was expressed by nearly all students as a chance to engage in a mobility experience that they would not have had otherwise while at university. For some, the online delivery overcame the travel barrier due to COVID-19:

> Because of COVID we can't exactly go everywhere and do the normal exchange programs, this still provides the opportunity to have some experience. (Chloe)

For others, the virtual environment presented new opportunities for cultural connections and learning with greater flexibility:

> It's nice to have a kind of exchange program online where you can have that sort of interaction and exposure and cross-cultural connection – even though you can't travel. (Sarah)

Engaging students in collaborative group work, rather than individual projects, was designed to enhance interdisciplinarity, challenge perspectives, and build connections between the Australian and Indian students. One student described it as similar to university work, but upon reflection, it "… was pretty wild thing that was happening" (Will). He elaborated further:

> Overall it was not too dissimilar to just any other group project but … little things that made me remember that it was also very different from a lot of other group projects that I'd done... I mean we were sharing ideas and perspectives separated by thousands of kilometres… That connection of thinking and ideas completely removed from each other was interesting. (Will)

However, as with all student group work, there are always difficulties. Collaborating online faced similar challenges, with the added pressures of technology and time zones. This experience varied from group to group. For some, the unevenness of participation and collaboration was frustrating - "not that I started to not like my group… but you've just got to try and make time for it." (Chloe). Whereas for others it was positive and proactive - "they're [Indian students] really keen to express all their ideas to me, and bounce them off me... that was pretty incredible." (Robert).

One student captures the highs and lows of the overall learning experience, later elaborating that "being online may have contributed" to some of the difficulties she experienced during the program:

> The cultural experience, even from online, it was quite good. Just dealing with students from across the globe; I've never really had to do that before so I found it really nice to learn some new cultural things, cultural challenges, cultural differences. Even the difficulties I learnt quite a lot from – so difficulties in language barriers and just understanding how students in India work and operate. (Olivia)

To enhance their online 'travel' experience, social and cultural activities were included within the program. One student, who does not "... even own a passport" (Sarah) shared that the inclusion of these cultural activities provided an opportunity to learn about another culture, one they might not have had access to otherwise - "That's not something I would seek out myself." (Sarah). For others, the experience was also an opportunity for reciprocity:

> I like getting introduced into another culture, I really like introducing Australian culture to another culture. They [Indian students] really thoroughly enjoyed when I started talking about Australia... (Robert)

Students also shared personal interests such as wildlife photography outside of the program and self-managed their research projects through modes of communication of their own choice, including WhatsApp:

> … we had a little WhatsApp group and we would discuss on there, "Well, I'm going to go and find out how many litres [cow milk] annually, so maybe you go and find the same thing for your side." (Sarah)

They chose collaborative applications like Google Docs to work on their projects and remain connected via social media after the end of the program - "... now we're good friends on Instagram" (Olivia).

Discussion

This case study has shared the students' perceptions and experiences through a short-term virtual mobility experience (VME). Reflecting on the program's co-creation, as well as the authors' prior experience in delivering in-country science OMEs and shared vision to develop future scientists who understand complexity, citizenship, and criticality in responding to global challenges, the design of the program did achieve its objectives. Acknowledging the active roles in knowledge production and interpretation (Braun & Clarke, 2019; 2022), and the limitation of perspectives and size, the findings address how sustainability capabilities were shaped in Australian undergraduate science students by the program design. Overall, the student participants expressed varying degrees of key education for sustainability (EfS) capabilities of sustainability thinking, collaboration, affective learning, critical reflection, and interdisciplinary knowledge (Thomas & Day, 2014). As with previous research, this study highlights that student learning and development must be nurtured, structured and well-planned (Towsin & Walsh, 2016), as evidenced by the program's approach. For the Australia-India Virtual Program, this included collaborative research, social and cultural activities, and reflective debriefs through a structured 8-week online program.

Research projects provided a real-world context and were supported through collaborative learning (Davidson et al., 2020; Stibbe, 2011). This provided an opportunity to "work on problems and explore responses" with students from different disciplinary and cultural backgrounds (Holdsworth & Thomas, 2021, p. 1478; Vriens et al., 2010). This approach particularly shaped the development of students' sustainability thinking, criticality, interdisciplinarity, and collaboration through experiential learning and intercultural dialogue. The INSPECT Model allowed for students to actively investigate agriculture as a holistic, interconnected system, incorporating natural, social, political, economic, cultural, and technological domains (Bawden & Packham, 1993). The Australian students showed a broadening of their perspectives through sustainability thinking in relation to this purposeful frame of inquiry. This shift varied amongst students, ranging from a nuanced understanding of sustainability dimensions to deeper critical evaluations of socio-cultural differences in agricultural practices, along with exploring complexity and interconnection.

In addition to the student's research activities, the program incorporated interdisciplinary perspectives of expert discussants and academics. This was designed to give a localised context to agricultural practices and sustainability challenges (Murphy et al., 2019). However, it was the peer-to-peer interactions between students from different STEM disciplines that appeared to be more prominently mentioned as fostering students' interdisciplinary knowledge and developing affective learning outcomes. Sharing their values, interests, and motivations, particularly towards environmental sustainability, students developed a strong sense of stewardship and connection. This was an unexpected outcome of the program, but one that allowed students to unknowingly reflect on their own values (Sterling & Thomas, 2006) - fundamental to affective development. This differs from the findings of Bell et al. (2016), whose research indicated that participating in a mobility experience led to a desire to make change and act. Students' experiences in this VME focussed more on solidifying their sense of shared responsibility to understand and act on sustainability challenges as young people.

Formal and informal online cultural and social activities enhanced the overall learning experience, whereby students were observers and active participants, not solely observers. Instances of shared storytelling through conversation, dance, food, photography, music, and place provided students with new insight into their peers and their respective homes more broadly. By embedding these within the program design, students were exposed to new opportunities, cultures, lifestyles, people, and perspectives outside of their daily norms (Hoyos et al., 2015; Potts, 2015). Students shared their appreciation for Indian culture and the newfound perspectives gained. These activities also enabled students to build early foundations that supported ongoing collaborative work. As with the study of Buchmüller et al. (2021), engaging in intercultural and interdisciplinary collaborations exposed students to their "shortcomings" about "other cultures, disciplines and social groups" (p. 6), which prompted reflection. Unplanned by the facilitators, the peer-peer exchanges on life, work and study also fostered other affective learning outcomes, such as empathy, respect, tolerance, understanding and appreciation for others (Buchmüller et al., 2021; Holdsworth & Thomas, 2021), effectively 'humanising' the online environment.

Debriefing provided the opportunity for students to engage in structured critical reflection (Holdsworth & Thomas, 2021; Pearson & Smith, 1985). Debriefs were embedded to help guide students' research progress, but within the program evolved into a space to talk about "observing new things and overcoming complications" (Boud et al., 1985). For example, the challenges of

collaborative work are compounded by distance and time. Similar to Tran et al. (2021, p. 902), students expressed moments of "value conflicts" (p. 9) as they navigated through the cultural differences in work practices. This 'conflict', however, in this VME aided critical self-reflection on their own assumptions and approaches, and exemplified professional practices and interdisciplinarity (Murphy et al., 2019).

These findings also support existing research that VMEs afford more equitable and accessible learning opportunities in periods of travel disruption (Hardiman et al., 2022; Vriens et al., 2010). Reflecting on this program, it becomes evident that VMEs may also allow for a more forgiving (i.e., a less confronting and fatiguing) introduction to the sustainability challenges faced in a country such as India than an in-country experience. However, VMEs are not without their own challenges - for the students involved or the facilitators who plan them. Communication and language barriers, uneven participation, internet connectivity, technology troubles, and differences in time zones, among others. While VMEs do not replace the true contextual and transformative experience, and often discomfort, of travelling overseas (such as sights, smells, sounds, food, unplanned interactions, or incidents) and demand a higher level of preparation, time and resourcing, they do present a compelling case for online alternatives that have the potential to foster sustainability learning and development and EfS capabilities from home (Davidson et al., 2020; Hardiman et al., 2022).

Conclusion

Higher education is faced with the responsibility of equipping students with the capabilities that must address complex global challenges. Recognising the STEM disciplines' vital role in responding to these challenges, preparing students by fostering sustainability capabilities is particularly necessary. These capabilities go beyond just job readiness; they build students' personal values and foster sustainable thinking through collaboration, interdisciplinarity, reflection, and engagement with real-world contexts. Appreciating the limited size and perspectives offered by this case study, overall, these types of virtual mobility programs have a positive influence on fostering sustainability capabilities, as evidenced by the Australia-India Virtual Program. The program design, inclusive of active experiential learning approaches intertwined with intercultural collaboration and dialogue, was critical to its success.

The outcomes of the program also hold implications for university learning and teaching. Largely, this case study demonstrates the effectiveness of well-planned VMEs in fostering sustainability capabilities among science students who are underrepresented in this space. In times when traditional in-country mobility programs (OMEs) may be challenging, costly, or disrupted, institutions should consider integrating VMEs into their curriculum. By incorporating active learning, collaboration, intercultural exchange, and reflection, universities can continue to nurture students and graduates who are well-informed, globally aware, and equipped to tackle complex global challenges.

Future studies could build upon this research to be more inclusive and explore the perspectives of all student participants (from all countries involved), as well as the perspectives of the facilitators. This case study, presented through the lens of students' experiences, offering deeper insight into its pedagogy and curriculum, aims to encourage the consideration, support, and

expansion of in-country and online programs across all disciplines, including STEM. These programs play a crucial role in fostering sustainability capabilities, now and in the future.

Conflict of Interest

The authors disclose that they have no actual or perceived conflicts of interest. The authors disclose that they have not received any funding for this manuscript beyond resourcing for academic time at their respective university. The authors have produced this manuscript without artificial intelligence support.

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