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New Frontiers: Fostering Students' Critical Thinking in Science Through Virtual Mobility

Brittany Vermeulen[1], Jenny Pizzica[1], Adrian Renshaw[1], Jason Reynolds[1]

Abstract

Virtual mobility experiences provide a valuable option to enrich student learning and development from home. However, there is a lack of evidence of how these online experiences are leveraged in STEM and their potential positive effect on students' critical thinking capabilities. This study explores and details the design of a short-term virtual program and its influence on science students' critical thinking. The program focused broadly on agriculture through the lens of sustainability and the SDGs whereby students engaged in collaborative research, reflection and intercultural interaction and dialogue. Analysis of students' learning journals and focus group responses suggest that students achieved the learning outcomes of the program related to critical thinking, nurturing students to think and potentially act differently while broadening students' personal understanding, connection, and confidence in relation to science. This paper discusses the experience from the perspective of the Australian undergraduate students.

Abstract in Spanish

Las experiencias de movilidad virtual ofrecen una opción valiosa para enriquecer el aprendizaje y desarrollo estudiantil desde casa. Sin embargo, existe una iclta de evidencia sobre cómo se aprovechan estas experiencias en línea en las áreas STEM y su potencial efecto positivo en las capacidades de pensamiento crítico de los estudiantes. Este estudio explora y detalla el diseño de un programa virtual a

1 Western Sydney University, Penrith, Australia

Corresponding author: Brittany L. Vermeulen, b.vermeulen@westernsydney.edu.au

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corto plazo y su influencia en el pensamiento crítico de los estudiantes de ciencias. El programa se centró ampliamente en la agricultura desde la perspectiva de la sostenibilidad y los Objetivos de Desarrollo Sostenible, donde los estudiantes participaron en investigación colaborativa, reflexión e interacción intercultural y diálogo. El análisis de los diarios de aprendizaje y las respuestas de grupos focales sugieren que los estudiantes lograron los resultados de aprendizaje del programa relacionados con el pensamiento crítico, fomentando que los estudiantes piensen y potencialmente actúen de manera diferente al ampliar su comprensión personal, conexión y confianza en relación con la ciencia. Este artículo discute la experiencia desde la perspectiva de estudiantes universitarios australianos (translation produced using AI).

Keywords

Critical thinking; science education; student learning outcomes; sustainability; virtual mobility experience

1. Introduction

With increasing social and environmental challenges globally the changing nature of the practice of science poses a new challenge for educators and students alike (Rodrigues et al., 2007). As such, critical thinking has been a developmental outcome across a range of disciplines in higher education, including most strongly science, technology, engineering, and mathematics (STEM). Science students (and graduates) are now expected to think differently as they explore and investigate the world around them. They must be able to think critically to interpret information from a wide range of disciplines, and meaningfully, actively, and ethically connect with the world around them to respond to these challenges (Davidson et al., 2021; Sarkar et al., 2019). One way of preparing science students to think more critically is through international learning experiences (Bunch et al., 2013), namely outbound mobility experiences (OMEs). OMEs are distinct from traditional 'study abroad' programs. They are shorter, flexible programs in which students "remain[s] enrolled at their home institution while travelling abroad for a component of their home degree" (Potts, 2015, p. 4). As universities work to make mobility more accessible and affordable (Harrison & Potts, 2016; Scharoun, 2015), the number of students travelling internationally is rapidly increasing. This also creates opportunities for universities to design and deliver innovative curricula and unique learning experiences for undergraduate students.

Mobility experiences make possible “intercultural and disciplinary outcomes by engaging people embedded in different contexts in collaborative explorations of common complex questions and challenges” in an increasingly “borderless” world, irrespective of “time, space, culture and discipline” (Rubin & Guth, 2022, p. 59). Many of these unique experiences may also be transformative and help students to “further elaborate and deepen our understanding of who we are and our relationship with others and the world” (Dirkx et al., 2006, p. 131).

The challenge, however, is that while OMEs have become a valued part of higher education in the last decade, the STEM disciplines are underrepresented in these short-term global experiences, with very few programs available to science students (Bell et al., 2016; Daly & Barker, 2005; Nerlich, 2016; Tran et al., 2021). Further, the global COVID-19 pandemic triggered an unforeseen disruption to student mobility, one that is not likely isolated (Hardiman et al., 2022). While universities have developed many international, domestic, and virtual curriculum initiatives, periods of border restrictions have accelerated the implementation of such online alternatives. Program coordinators and institutions are being encouraged (e.g., Australia’s Department of Foreign Affairs and Trading New Colombo Plan Project) to continue to design and deliver their international mobility programs to fill this sudden gap. Virtual mobility experiences (VMEs) - also known as collaborative online international learning or virtual exchange - are described as a “bi-lateral online exchange involving the integration of existing courses across two, or sometimes more, institutions that are geographically and/or culturally distinct.” (Rubin & Guth, 2022, np.). Using technology to facilitate learning and collaboration, these online experiences engage students in the learning activities of identifying, developing and critically evaluating ideas and information, supported by active, experiential pedagogical strategies (Ash & Clayton, 2009; Davidson et al., 2021; Rayner et al., 2013; Villar-Onrubia & Rajpal, 2016; Vriens et al., 2010). How VMEs can be implemented in undergraduate science curricula more broadly is under-researched. Even less is reported about how these virtual experiences can have a positive effect on students’ critical thinking capabilities (Hardiman et al., 2022; Vermeulen et al., 2024).

2. Literature Review

2.1. Unpacking Critical Thinking

The nature and importance of critical thinking is an active site of debate in higher education (Davies & Barnett, 2015). Arguments are to be made that characterize critical thinking as a way of doing and being in the world rather than as a generic skill to be acquired or taught. Experiences "may challenge at a deep and fundamental level our existing ways of thinking, believing, or feeling." (Dirkx et al., 2006, p. 132).

Brookfield's (1987) view of critical thinking supports this as it involves questioning assumptions and being ready to think and act differently. Critical thinking involves the interconnected components of identifying and challenging assumptions, recognizing the influence of context, imagining and exploring alternatives, and being reflective and skeptical of claims to universal truth (Brookfield, 1987). This means students who are critical thinkers explore, critique, argue and question the world around them (Santos, 2017).

Critical thinking may best be shaped through transformative, active, experiential, inquiry-based or problem-based learning within a disciplinary context (Dirkx et al., 2006; Wilson & Howitt, 2016). According to Bailin (2002, p. 368), critical thinking "takes place in response to a particular task, question, problematic situation or challenge, including solving problems, evaluating theories, conducting inquiries, interpreting works, and engaging in creative tasks". Critical thinking comes more easily to students when they experience learning as personally meaningful (Volman & ten Dam, 2015) and when they can exercise control and choice in their learning, with support and feedback from peers and instructors (Vardi, 2015).

Critical thinking also has social and ethical dimensions. While critical thinking can be enhanced when students collaborate with peers to discuss ideas and examine different perspectives such collaborations need to be directed at activities that "have value and meaning in human society" (Volman & ten Dam, 2015, p. 598). Brookfield (1987) acknowledges that the complex process of critical thinking entails 'facing up' to ethical dilemmas. It involves a deeper awareness of the diversity of values, worldviews and social structures that exist in the world, which then informs students' ways of thinking and acting. Such individual abilities are contextually influenced or bound by external circumstances, such as the socio-political environment where real-world situations and solutions are multifaceted, complex, and messy (Brookfield, 1987; Golja & Clerke, 2020; Rubin & Guth, 2022; Wilson et al., 2015; Wilson & Howitt, 2016).

2.2. Critical Thinking and Problem Solving in STEM

Critical thinking in STEM is closely linked to problem solving. For some educators, they are the same, but for others, it is not possible to solve problems without thinking about them critically first (Jones, 2015). While there are overlaps in how both are exercised by students, they are distinct from one another. Problem solving involves identifying obstacles and then strategically mapping out solutions (Garrett, 1986). This linearity in identifying challenges and developing solutions has been criticized for failing to develop students' capability to solve open-ended problems in complex and unpredictable circumstances and limiting opportunities for students to critically engage with real-world challenges (Sarkar et al., 2019). In science education, the definition of critical thinking pivots on the idea that critical thinkers can solve problems and make informed decisions based on reasoning and logic through the application of scientific principles, methods, and technologies (Santos, 2017; Wilson, 2017). However, fostering critical thinking in STEM students (and STEM education by extension) in a changing world must encourage students to explore beyond their discipline context, to think critically, ethically, and creatively (Davidson et al., 2021; Sarkar et al., 2019).

2.3. Fostering Critical Thinking for STEM Students Through Mobility Experiences

Programs in STEM that rely on experiential inquiry, real-world research or work-based experiences have been shown to develop students' core capabilities, including critical thinking, problem solving, creativity, scientific literacy, and scientific identity (Bamber & Pike, 2013; Murphy et al., 2019; Oliver, 2015; Sanders & Hirsch, 2014; Townsin & Walsh, 2016; Adkins-Jablonsky et al., 2020). Mobility experiences, both physical and virtual, provide an ideal space to design innovative experiences that have the potential to foster students' critical thinking (Authors, 2022). The OMEs that have reported positive changes in students' critical capabilities are programs that pay careful attention to the development and evaluation of specific components of critical thinking in the design of their programs. Three such examples are considered in greater detail below.

Students are more likely to develop critical thinking when they can personally connect their disciplinary knowledge and explore new knowledge and perspectives (James & Brookfield, 2014; Jonassen et al., 1999). McLaughlin and Johnson (2006) delivered a short-term OME focused on exploring real-world environmental and conservation field research for undergraduate science students to facilitate critical thinking and illustrate the scientific process. Hands-on work in the field and reflective journals were integral to the course's experiential design. They found, as a result of the programs' design that nearly all students demonstrated varying learning gains from their first assessment task. Students reported conceptual learning gains in several areas related to critical thinking in the context of ecological issues - the ability to make informed decisions on ecological issues; to think critically about complex conservation issues; and to think through a problem or argument as it pertains to the environment. McLaughlin and Johnson (2006) go further to state that exploring and questioning environmental contexts "enhances the understanding of biological concepts and instils in students an environmental ethic." (p. 77). This is particularly relevant to actively and ethically connecting STEM students with the world around them to respond to global sustainability challenges (Davidson et al., 2021; Sarkar et al., 2019).

Exploring how science is understood and practiced in different cultural and geographic contexts can also be beneficial in fostering critical thinking (Guest et al., 2006). Tran et al. (2021) found that observing different 'ways of doing science' aided the development of critical thinking in students. Their program design saw students engage in a short student-led research project which included a marine science-intensive course, research project and international symposium. Development of critical thinking was reported via analysis of students' post-trip interviews. Students' critical thinking was fostered by "observing different practising communities" (Tran et al., 2021, p. 902), with their research project being a learning tool to develop other 'skills' such as teamwork, communication and problem-solving. In their more recent paper, Tran et al. (2022) further explored this study tour through the conceptual framework of 'knowing, acting, and becoming'. Using this framework for analysis of post-trip interviews, critical thinking was also reported through cross-cultural interactions and engagement with Japanese culture. This setting challenged students to think critically about their assumptions and beliefs as they encountered different cultural perspectives and scientific practices, which can lead to a reported deeper understanding of themselves and others. Both studies suggest the potential of OMEs to promote critical thinking by encouraging students to challenge their preconceptions about science by engaging in and with diverse cultural environments.

Studies have identified that reflection facilitates student's critical thinking. By reflecting, students can explore questions, challenges, and insights (Schmidt & Brown, 2016). Reflective practices also allow students to think deeply about their learning experiences, connect new knowledge to prior knowledge, and draw personal meaning from the experience and learning content. Roberts et al. (2018) used reflective journals (guided by daily prompts) to explore critical thinking amongst a small group of science students. Using thematic analysis and Facione's (1990) critical thinking framework, the study found that students exhibited some critical thinking capabilities such as exploring alternate agricultural practices or questioning their preconceived ideas and assumptions of the local people. A supplementary paper from Roberts et al. (2019) further analyzed this short-term OME from an intercultural learning perspective. They found critical thinking was fostered through concepts of awareness of culture and understanding of agricultural issues aided by reflection and stimulated by the physical surroundings and social interactions with the local community. As demonstrated, reflection must be incorporated as an intentional aspect of program design in OMEs. This allows students to question their values and assumptions as they learn, leading to a deeper understanding of their discipline and its broader applications in the world.

While fostering critical thinking capabilities has been shown through physical OMEs, there is very little available on the potential of virtual mobility experiences (VMEs) to develop critical thinking for undergraduate STEM students. Most studies have highlighted that VMEs can achieve broad learning and development for STEM students, such as Vasquez and Ramos (2022). Reviewing previous implementations of VMEs in the higher education literature, Vasquez and Ramos's (2022) findings suggest that successful programs require collaborative and cooperative teamwork, motivation to learn from other students and cultures, mutual respect, constant communication among facilitators and students, and assigning activities related to open-ended questions. The potential to foster students' critical thinking more specifically in these virtual programs remains relatively unknown for STEM and in particular science. Further, there is very little evidenced theoretical analysis of how these virtual learning experiences fostered critical thinking compared to OMEs in this field. Watla-iad and Hartwell's (2022) paper discusses a collaborative virtual program, where students produced a shared assessment. The program was successful in its aim to enhance students' scientific literacy, intercultural teamwork, digital literacy, and work ethic. While providing students with a broader view of both sociocultural and analytical aspects of chemistry, Watla-iad and Hartwell (2022) draw upon the idea of 'practising' critical thinking as involving students "critically reading the research article, researching information through a scientific database, evaluating data, preparing and giving the presentation, and understanding more of analytical chemistry" (p. 1073). While this fits into the standard definition of critical thinking in science education, it does not consider the transformative and meaningful notions of critical thinking a VME can potentially offer.

As such this paper presents a recent VME, co-designed by two educational partners in Australia and India with the goal to foster critical thinking. The short-term program was delivered online and brought together Australian and Indian students (undergraduate and postgraduate) in a bi-lateral exchange to critically investigate agriculture and sustainability in view of the United Nations' Sustainable Development Goals (SDGs) through a structured eight-week program. The study explores the potential of this VME design to foster students' capabilities using data collected from learning journals and focus groups. This study seeks to address the question: How can virtual mobility programs be designed to facilitate critical thinking in an international (online) setting?

3. Designing Learning Environments to Support Critical Thinking: The Australian-India Land and Water Virtual Program

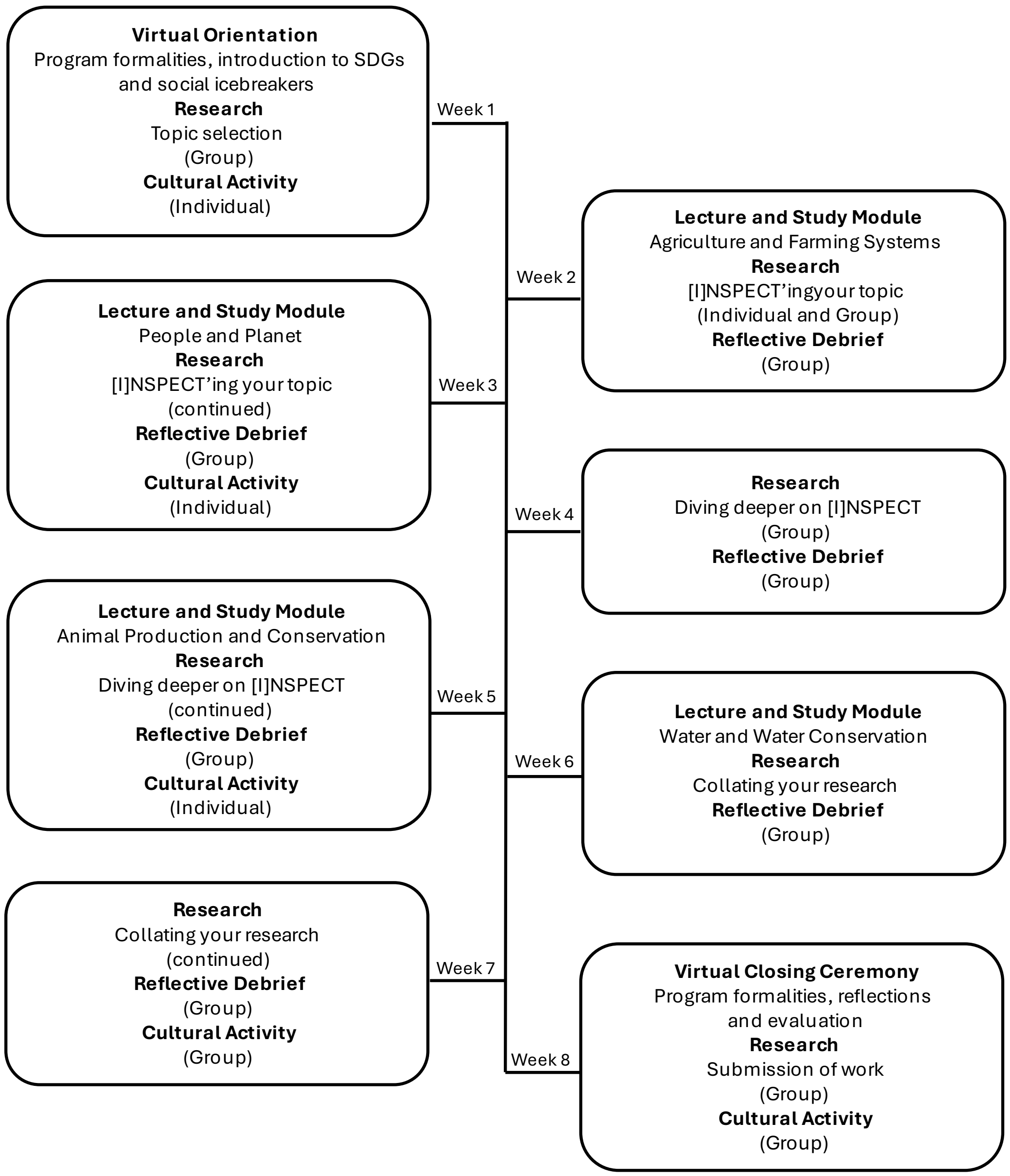
3.1. Program Summary

The Australia-India Land and Water Virtual Program was a co-designed online global program open to STEM students during travel restrictions imposed during the COVID-19 pandemic. The structured eight-week program was delivered in July – August 2022. Weekly two-hour synchronous sessions (via video-conferencing technologies) were coupled with two hours of supplementary self-led learning and reflective journaling. The program explored topics in agriculture through a sustainability and SDG lens in both Australian and Indian contexts. This included agricultural issues linked to agriculture, livelihoods, gender, biodiversity, water, consumption and production, and climate change. As an academic discipline, undergraduate agricultural degrees are promoted as a means to "learn the scientific fundamentals" (Open Universities Australia, 2023). However, the VME expanded on this focus and engaged students in a broader exploration of agricultural practices and principles through social, economic, and environmental dimensions.

The program was run entirely online with weekly two-hour synchronous sessions, as shown in Figure (1) on the following page. The program commenced with a synchronous orientation session (Virtual Orientation) where students formed research groups and selected a group research topic (Research) and then individual ice-breaker activities detailing their professional and personal interests (Cultural Activity). The proceeding weekly sessions consisted of formal lectures from Australian and Indian experts giving context to localized agricultural-related topics; informal synchronous and asynchronous cultural and social activities; a bi-lateral collaborative research project which included weekly scaffolded tasks, submission of group work and reflective debriefs; and self-guided e-learning materials and resources (see Supplemental Materials for an outline of the weekly research tasks). More detail on the design of this virtual program, as well as outcomes for students in terms of fostering key sustainability capabilities, is available (Vermeulen et al., 2024).

Figure (1)

VME for critical thinking: weekly program design



The VME engaged 31 STEM students in total (eight Australian and 23 Indian) from all levels of study (undergraduate, honors, postgraduate and higher degree research). The Australian students were drawn from one university in a targeted call within two subjects. Participating students were domestic undergraduates enrolled in Science. In contrast, the Indian students applied to participate via a nationwide open call through the Australia-India

Water Centre network and the Centre for Environmental Education (CEE) Academy, representing 18 different Indian universities. All participants were enrolled in varying STEM programs including Engineering, Information Technologies, Biotechnology, Agriculture and Physical Sciences.

Participating students received a digital co-credential as a recognition of their participation in the program, and Australian students received academic credit from their home university. Existing New Colombo Plan (NCP) funding subsidized the cost of participation of all students.

3.2. Program Learning Objectives

Critical thinking was the crucial consideration in the objectives, design, and implementation of this VME. By incorporating learning activities that encourage critical thinking in personally meaningful contexts, such as collaborative research, intercultural interactions, and reflection, this online program offered unique opportunities that expanded students' perspectives, cultivated global awareness, and fostered student development (Rubin & Guth, 2022; Tran et al., 2021). Below we detail the two program learning objectives intended to develop students' critical thinking, and the learning activities aligned with those objectives (note the other program learning objectives aimed to support complementary student development, including enhancing collaborative teamwork capabilities with others from different backgrounds, and improving their scientific communication skills).

3.2.1. Learning Objective 1: Engaging and Developing Students' Critical Thinking to Address Real-World Agricultural Challenges

The interconnection of science (agri-) and people (culture) was an important foundation in the design of the program. Agricultural challenges provide a rich context for exploring the interaction of social and natural systems while emphasizing practical problems faced by real people (Roberts et al., 2018). Addressing the complexity of these interconnected challenges, within the broad context of science, requires students to think and act differently (Brookfield, 1987; Davidson et al., 2021; Dollin et al., 2023; Sarkar et al., 2019). Critical thinking was encouraged through collaborative research, transdisciplinary inquiry frameworks, and reflection.

Working in small bi-lateral student teams over the eight weeks to research an agricultural product of their choosing, the students undertook a series of defined and scaffolded tasks (see Supplemental Materials for details). Scaffolded tasks were provided with explicit guidance to support students in an online and cross-cultural environment. Student teams were provided with time during class to complete research activities (via breakout rooms), with the expectation of additional collaborative work which would be self-managed and undertaken outside of class. Differing from scientific research projects, where students often design an experiment, the research question was more open-ended (Vasquez & Ramos, 2022). Through four defined tasks, students worked towards answering "How does the farming product you selected to research compare or contrast between countries across the [I]NSPECT domains selected?" Each student team submitted a joint video presentation, written summary, and group reflection on their research project in response. Their joint work was submitted at the conclusion of the program (in Week 8).

The [I]NSPECT Model (Bawden & Packham, 1993) was used to explore the agricultural product selected. The framework provides a lens of inquiry to explore a defined (usually environmental) challenge from several different perspectives and influences – Natural, Social, Political, Economic, Cultural and Technological – where the interpretation ([I]) of such reflects the individual's personal worldviews, understanding and context. The framework recognizes interconnectedness, complexity, and uncertainty, and reinforces the notion of transdisciplinarity (Bawden & Pachkam, 1993). This allows students to use their prior discipline-specific STEM knowledge to investigate transdisciplinary perspectives and was adapted for use in this VME becoming a catalyst for critical thinking.

Reflective debriefs, learning journals, online polling, and peer-to-peer feedback were implemented at different stages of the program to provide opportunities for all students to discuss, share, and reflect on their research insights and learning with the larger cohort. At the end of each live session, each student team was called upon to provide an update on their research with feedback and guiding prompts given by the facilitators. In addition, students were provided with an electronic learning journal that included weekly templates and prompts to encourage reflective thinking. These prompts aimed to help students reflect on their learning experience, research progress and personal development with questions guided towards critical thinking. Learning journals also encouraged reflective thinking with questions guiding students towards reimagining the work of STEM professionals. By providing structured reflection opportunities regularly (Hatcher & Bringle, 1997) students were enabled to explore, critique, and question their assumptions and disciplinary views of agriculture, sustainability, and science.

3.2.2. Learning Objective 2: Supporting Cross-Cultural Dialogue, Diverse Perspectives of Science and Developing Peer Networks

VMEs promote both intercultural and disciplinary outcomes by bringing people from various contexts together to explore complex, multifaceted questions (Rubin & Guth, 2022). This was facilitated in this program through peer-to-peer interactions and dialogue, intercultural learning activities and expert discussants to add a meaningful and authentic aspect to the program and enable students to apply and connect with the content and one another.

Throughout, peer-to-peer interactions and dialogue – including social, cultural, and collaborative activities – were prioritized. Students from each country were engaged in synchronous and asynchronous activities, such as live cultural performances and individual bi-weekly online discussion posts. Activities were coordinated and encouraged by the program facilitators, such as facilitating virtual games and icebreakers. Prompt questions and guiding examples were provided via the e-learning platform for asynchronous activities, such as sharing traditional recipes, to engage independently. Students were also encouraged throughout the program to build their networks outside of class, taking it upon themselves to connect through social media apps like Instagram and WhatsApp.

Bi-weekly lectures offered a localized context, providing stimulation for alternative ways of thinking and doing, and were delivered live by STEM academics and sustainability practitioners. The lecture block included an expert from each country. Each block explored a predefined topic of sustainability and agriculture from the interdisciplinary perspectives of the expert discussants and was coupled with a study module on the e-learning platform. Supplementary materials (videos, readings, recorded lectures, and additional resource links) were provided. The program facilitators were also from diverse cultural and disciplinary backgrounds, providing further insight through sharing their own experiences and providing feedback during reflective debriefs. As Brookfield (1987) notes, facilitators can become critical thinking ‘helpers’ by actively listening, providing reactions, making connections, and encouraging the identification of assumptions and skepticism.

By providing formal and informal opportunities to engage with individuals outside of their home context, the program provided space for students to engage in a diverse range of immersive and intercultural learning activities that shaped an environment to challenge their assumptions and encourage them to think outside of their usual frameworks and contexts.

4. Methodology and Methods

This study explores the potential of a short-term virtual mobility experience (VME) to foster science students’ capabilities. Data were drawn from an analysis of students’ learning journals and focus group responses (five student participants total). A constructivist approach was adopted to interpret differing student perspectives and comprehend their lived experiences of the described VME (Creswell & Plano Clark, 2018; Creswell & Poth, 2018). The authors used reflexive thematic analysis to generate two themes.

4.1. Data Collection and Participants

Two online focus groups were conducted by the primary researcher, two to three weeks after the VME concluded. Identical sessions were held to account for student availability, each lasting 90 minutes. The audio was digitally recorded and transcribed. Students were invited to participate in the research after their virtual orientation (Week 1 of the VME program). Of the eight Australian students who enrolled in the described VME, six students completed and were eligible to join the study. Five agreed to do so. Participants were current students enrolled in a Bachelor of Science from the same Australian university (Table 1). All participants were domestic undergraduates from varying science majors. Pseudonyms were given to each participant to maintain anonymity.

During the focus group, participants were asked to discuss their learning experiences, research projects, and future career pathways. As part of the program, all enrolled students (Australian and Indian) were provided an electronic learning journal and were encouraged to complete weekly reflective entries. Focus group participants provided the primary researcher with a copy of their journals for analysis. In the time allowed, ethical approval for the study could not be obtained to allow interviews with Indian students. This study therefore focused on the Australian students' perspectives.

TABLE (1)

STUDY PARTICIPANTS AND THEIR FIELD OF STUDY WITH A BACHELOR OF SCIENCE

Pseudonyms	Gender	Field of Study (Major)	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	3rd year

*FINAL YEAR STUDENT

4.2. Data Analysis

Reflective thematic analysis (TA) was used to identify and explore the richness and complexity of student learning and development, with attention given to critical thinking. Reflective TA (Braun & Clarke, 2019), foregrounds and emphasizes the researcher's interpretation, subjectivity and reflexivity in coding and theme development to uncover deeper meanings and experiences beyond content analysis (Braun & Clark, 2019; Terry et al., 2017).

Guided by the analytic process of reflective TA, Braun and Clark (2019, p. 34) suggested "six-phase process" was used to develop themes from the focus group transcripts and learning journals (Braun & Clarke, 2019, 2022). In the familiarization phase (phase 1) the primary researcher listened and read over the transcriptions simultaneously, taking notes briefly detailing notable and interesting mentions of learning and development from each transcript. The student learning journals were reviewed with further notes taken per participant. Moving onto the coding phase (phase 2), the primary researcher used Brookfield's (1987, p. 15) two "central components" of critical thinking – namely, (1) identifying and challenging assumptions and (2) reimaging and exploring alternatives - as pre-established categories. Excerpts that seemed to describe these categories were extracted from the transcripts and learning journals and collated for further analysis. Each author then individually read the excerpts, creating, and sharing codes relevant to the research question. The authors agreed on 40 preliminary codes that best illustrated the student experience. The codes covered the central components important to critical thinking (Brookfield, 1987), amongst others developmental outcomes, and the connections between those experiences and elements of the program design.

These coded excerpts were then further analyzed and condensed by the authors through a collaborative discussion to generate initial themes (phase 3) and undertake a shared review of the themes (phase 4). Themes were further refined and defined to arrive at the final agreed themes (phase 5). Through this process, multiple themes were collapsed and shifted, and two final themes were arrived at: (1) "Fostering critical thinking by exploring science and agriculture through virtual experiences" and (2) "Constructing meaningful learning in a virtual environment to explore science and sustainability". The findings were jointly reviewed and written up (phase 6) and are detailed below.

5. Findings

Overall, the insights shared by the undergraduate Australian student participants indicate that the program fostered student learning, development, and critical thinking. The design of the VME provided the opportunity to navigate across cultural and international borders digitally, fostering a broader, more global perspective that explored agriculture, sustainability, and science. This was particularly illustrated in the students' perspectives of themselves, their assumptions and views, and their willingness to explore alternatives regarding their discipline and sustainability.

5.1. Constructing Meaningful Learning in a Virtual Environment to Explore Science and Sustainability for Critical Thinking

While the program sought to foster critical thinking in meaningful contexts, students developed personally meaningful learning through their active engagement in the VME. According to James and Brookfield (2014), student learning is "deepest" when the subject matter or capabilities being learned are "personally meaningful" (p. 6). This was expressed through the students' prior personal interest in sustainability before the commencement of the program, attracting them to the program and motivating them to join. Demonstrated in their learning journals, students also expressed their desire for a greater understanding of global perspectives through new knowledge and sharing with others. For some, this was focused on sustainability:

> I hope to expand my own knowledge on sustainability and what it means to be sustainable whilst still respecting others' beliefs, ethics and values on the topic. (Chloe)

> I hope to expand my understanding on intrinsic and extrinsic values of animals and environment across different beliefs and countries. (Robert)

Other students expressed a curiosity for exploring different global contexts - "… [I was] looking to learn some new things, particularly from an international perspective." (Olivia). One student expressed his desire for a broader global view, reflecting how his personal attributes would be useful in connecting with their peers and the subject matter:

> I hope to achieve a greater understanding of the different approaches taken to global problems by people of diverse backgrounds… I am empathic and open to seeing things from many perspectives, which will help in connecting with people from different cultures. (Will)

The combination of peer-to-peer interactions, collaborative research and expert discussions included in the program design was found to assist students to develop new knowledge and perspectives for a deeper understanding of sustainability. Learning that is personally significant can "deepen our understanding of who we are and our relationship with others and the world" (Dirkx et al., 2006, p. 131), which has the potential to foster critical thinking. The in-depth exploration of environmental challenges from those experiencing them (i.e., their Indian peers, facilitators, and experts) helped students make meaningful connections with their prior learning and interests:

> Having learnt about the difficulties with pollution that India faces throughout some of my other units, I … wanted to delve a little bit deeper into some Indian perspectives on waterway health and soil quality… [W]hen you're looking at environmental pollution issues, I think sustainability and improved practices comes hand-in-hand… you obviously look at the issue but you want to learn how you can also fix it. (Olivia)

According to one student, the program helped him to find relevance, renewed meaning, and new knowledge as he explored specific areas of social and environmental sustainability in the context of agriculture in India:

> I learned heaps of really specific knowledge [about India]… fighting against government decisions … and the work that people are doing to improve their situation… all the stuff around like nitrification … fertiliser loading; all of that was all news to me... I didn't really have any specific knowledge going into the programme about what was actually happening in India … I learned a lot of really specific things about sustainable land and water use around farming…" (Will)

The learning activities also further fostered students' confidence and self-efficacy in science (Jonassen et al., 1999). Reflective debriefing and the collaborative nature of the VME contributed to students' engagement with the program. For one student this inspired a sense of reassurance in their disciplinary capabilities as they moved towards becoming a young scientist:

> … [A]fter I kind of presented [reflective debrief] … they [program facilitators] kind of gave like that positive feedback and then like had the question of, "What about this area?" and, again, I had the response to it; it wasn't like I was trying to still find it somewhere… I'd be like, "No, like I've covered that part in my research, here you go"...". (Chloe)

Chloe reflected further and highlighted her growing expertise and sense of belonging in her chosen discipline because of the program, stating,

> It kind of made me think, "No, I kind of know what I'm talking about; I do have some knowledge in the area I'm interested in"... "Yes, you're… in the right space." … I'm … definitely not meant to be like a maths teacher… science is more my area and what I'm interested in. (Chloe)

For others, debriefing and collaboration provided reassurance through their active involvement in the learning process, helping to make them feel valued and remain invested in the VME:

> Having like debriefs … after the meetings when we would kind of come back together … or even just being involved in like email chains, that really affirmed the fact that I was doing this thing [the VME] with you guys [program facilitators]; it was like this cooperative project. (Will)

Exploration of individual aspirations and future career orientations through the VME also assisted students to see new possibilities for working in science – "some people [enrolled participants] were just beginning their degrees, while others were PhD students. Some had no workplace experience while others were already working as scientists..." (Sarah). Participants highlighted the potential value of engaging with international career opportunities and acknowledged the program's eye-opening effect on the possibilities and meanings of a science career, especially in an international context. For one student, Will, this solidified this option: “I’ve already wanted to be able to take my degree overseas and apply it in an international context... [the program] reaffirmed the possibility and… the potential value of doing that.” This sentiment was shared by other students who recognized the value of working with diverse groups of individuals from different cultural backgrounds and a sense of confidence in their ability to do so in the future, as recorded in his journal: “I can work with a diverse group of people on different cultural subjects in relation to science” (Robert).

By engaging with experts and students from India, the VME “… made me more aware of the possibilities and what it [science] might mean” (Sarah). Although Sarah noted that personal circumstances would make it difficult for her to work overseas, she reflected on how the program had helped broaden her personal view of science - how it could take different directions and hold varying significance for individuals in diverse places:

> … [The program] opened my eyes about some of the places you can take the career – a career in science… working with international organisations and overseas… the different sort of challenges that people face overseas, so their sort of scientists going in different directions that might be more relevant to them… it [science] means different things to different people in different places. (Sarah)

The exposure to global possibilities within their disciplinary contexts allowed students to explore different intercultural and disciplinary values and perspectives. Facilitated through interactions and dialogue with experts and peers, this VME acted as a meaningful experience for exploring new and alternate pathways of science, while supporting and broadening students' understanding and knowledge of social and environmental sustainability challenges.

5.2. Fostering Critical Thinking by Exploring Science, Agriculture, and Sustainability Through Virtual Experiences

Critical thinking comprises two central components: identifying and challenging assumptions and reimaging and exploring alternatives (Brookfield, 1987). In the design of this VME, there was a deliberate focus on promoting critical thinking by providing students with opportunities to explore, compare and challenge the principles and practices of agriculture in relation to sustainability and the SDGs. However, observing and engaging with diverse practices of science also led to participants challenging their underlying assumptions and biases towards the familiarities of the student's discipline.

According to Brookfield (1987) individuals are prompted to become critical thinkers by an external stimulus, such as a teacher presenting alternative ways of thinking or an unanticipated event. Diverse expert discussants - academics and practitioners - were included to ground the information in a local context, exposing students to different approaches and new understandings. This sparked a realization for participants that science can take diverse forms and open new possibilities, challenging their assumptions. One student, Will, described a "light bulb moment" when seeing a discussant working in water resource management, dressed in traditional clothing while discussing the scientific aspects of their field. This experience challenged Will's assumptions about how science is typically practiced and highlighted the diversity of scientific practices around the world:

> One of the guest speakers who was working in water reservoirs, and some of the pictures that he put up on screen of the different farms that he'd worked at… seeing him in this like beautiful red and gold and silver gown being like next to a dam, and then him talking about all of the hard chemistry and all of the hydrology… that was a … light bulb moment… seeing those two things can accompany each other. (Will)

Another student, Olivia, echoed this sentiment by recognizing that science can take different forms beyond the typical white coat seen in their home context: "Different from the typical white coat and PPE [personal protective equipment] that we see our [Australia] side of the world."

Critical thinking also involves alternating phases of analysis and action, where capabilities are developed and refined through active inquiry (Brookfield, 1987). For one student, Will, these critical thinking "phases" (Brookfield, 1987, p. 23) were apparent in his changed understanding of scientific practices and pursuit of sustainable development. Triggered by the experience and new insights and information, Will acknowledged the misconception held about the practice of science in India prior to the program and recognized the cutting-edge nature of scientific work happening there. Scrutinizing his views, he became more aware of the discipline's global diversity:

> I suppose it was nice to see that science in India is just as cutting edge as I perceive it to be everywhere else… I had a misconception that India was a less developed country – for whatever reason, being isolated in Australia, but realising that people are really onto shit, and they're really pushing ground and doing amazing things... (Will)

He further elaborated on the impact the program has had on his thinking, becoming "more scientific" (Will). This led Will to a more skeptical examination and exploration of the discipline, noting a sense of detachment (or objectivity) of science which is comparably different to its practice in India. Highlighting the importance of cultural relation to the land and how it contributes to a different approach - "[it depends] what lens you're looking through." - Will begins to develop alternative perspectives and challenges the narrow definition of science from his home context:

> … I've actually been reflecting in the last few months that my… thought process around just anything, the way that I rationalise things and the way that I … try and problem solve now, is very much more scientific than it used to be... But I also think that science can be fairly cold and – if I can personify a word, like science can be kind of arrogant… [L]ooking at people's cultural connection to the land in India and indigenous Australians' connections to the land, that's not necessarily what a lot of people would call science, and yet it's still based on understanding and observation and connection... (Will)

This integration of his new understanding shows the potential transformative nature and personal significance of this VME in the future orientation of working in science and scientific undertakings, expressed by Will: "[its] shown me another application how you can apply science when there's a lot of other factors involved." For another student, Sarah, the VME provided exposure to new ways of working and living. As she indicates below, even though she had elected to join a program with students from another country, she realized she had previously ignored the difference between countries and everyday practices: "I really hadn't put much thought into different ways of life over there [India]... I didn't have too many preconceived notions, purely because I just never really considered it... ."

Critical thinking was also evident in the students' reflection and skepticism of the agricultural industry. The [I]NSPECT Model (Bawden & Packham, 1993), used as an inquiry framework for collaborative research, played a crucial role in challenging assumptions and exploring alternatives from a transdisciplinary viewpoint of agriculture and sustainability. Conceptualizing the world's complexity and interrelatedness at multiple scales is critical to student learning (Rubin & Guth, 2022). Participants felt their assumptions were challenged as they explored diverse viewpoints and alternate practices, resulting in a new understanding of the complexities and ethical dilemmas in agriculture. Their research enabled them to personally question their assumptions and reimagine different ways of doing things:

> … [T]his [VME] did give me the opportunity to challenge any ideas that I already – pre-conceived notions. We do live in a country that has the better laws when it comes to our animals, so it's figuring out like what other people's values... something that makes you think like, "Yes, this could be done this way. Or this could be done that way. Or there's always a better way to do it." (Robert)

Technology - one of the six [I]NSPECT domains - was the domain most students focused on in their research projects, likely due to its familiarity with the STEM disciplines and the assumed contrast of advancement between countries. Multiple students critically examined the use of automation and technological advancements in modern agriculture for good and for bad, exploring alternatives. One student expressed the potential of technological advancements in the hemp industry to address issues of inequality in India and the opportunity to foster improvement and collaboration between countries:

> The hemp plant really does provide opportunities… They're [India] using the products in so many different things … textiles … to fuel, and they are experimenting with building products. … [W]e [Australia] could definitely work with them... And vice versa, we have more advanced machinery to cultivate the product whereas over there … their cultivation is manual and then … therefore comes the inequalities between how people are treated … [W]e could really work together to learn a lot from one another, and kind of… create an equity between how the product can improve both of the countries, and how it can be done better. (Olivia)

For another student, the economic disparities and equity differences between countries were difficult to remedy as optimistically. By actively questioning and examining the complex and interrelated sustainability aspects of the wool industry, Chloe engaged in critical thinking by considering the implications of these different perspectives and motivations influencing agricultural practices and comparing countries. She elaborated,

> … [F]or us [Australia] it is such a large economic gain but it's not to the same extent for them [India] for the amount of work put in… they have to work so much harder … … for them to be ninth in the world and … 2 million people employed, and Australia to be the highest ranking with only 200,000 people employed, it was … a big difference to like kind of realise … a lot of [Indian] farmers that mainly have a couple of sheep, and they'll sell the wool basically just to kind of put food on the table, to have some kind of income. Whereas I know quite a few people that might have just a few sheep because it's a pet, they don't have it for any other reason but they like the animal. (Chloe)

Exploration and comparison of diverse perspectives and motivations shaping agricultural practices between the two countries, particularly on "different scales" (Will), was also a point of critical thinking for others. The comparison led to an inquiry into alternative approaches for different outcomes based on contrasting values and agricultural practices. Reflecting on the rice industry, Will elaborates,

> … It is interesting to see where values lay and how different values can really influence how resources are managed. I feel like there's often such a disconnect between political goals and then people's individual goals … like the whole controversy between the push to use more fertilisers and [Indian] farmers literally saying like, "We can't. If we keep doing this, our land is not going to be viable. We can't keep doing this." But they can't afford any other means of fertilisation… I guess that comes down to what each country values around that product and in Australia it's really an economic thing; we can produce rice fairly cheaply, fairly water effectively, and sell it ... But for India, it's more of a part of life... they're farming it to keep themselves fed and to keep their communities fed… a massive difference in values and … approaches. (Will)

While research was an important tool to foster critical thinking in this VME, 'helpers' (i.e., the program facilitators from Australia and India) also played an important role in fostering critical thinking by aiding individuals to "break out of their own frameworks of interpretation and providing new viewpoints for thinking and acting" (Brookfield, 1987, p. 29). The facilitators worked together to co-create the program to ensure students were pushed out of the 'normalness' of their everyday lives - from implementing the [I]NSPECT Model to the incorporation of social and cultural activities to support peer-to-peer interactions. Reflective debriefs supported student learning, as well as meaningful and active engagement, focused mainly on their research. Held at the end of each weekly synchronous session, facilitators provided guidance and direction to explore new elements of their research. This was a useful exercise for the student teams to explore alternate ideas and processes:

> It was helpful each week when we sort of presented what we had done so far, getting that bit of feedback and we would get suggestions about other things you could maybe look into… one of the facilitators… [suggested] going and looking at how much wastage there was... that was helpful having that sort of… advice or suggestions given about what other kind of things we could be looking at. (Sarah)

> [W]hen we went from six [domains] down to two, we actually had to widen our field of research so that we had more specific connections between those domains…. And honestly… what [program facilitator] said in one of those meetings made me realise like, "Yes, we're kind of going in the wrong direction." (Will)

Overall, the VME provided students with new perspectives, connected with personal interests and disciplinary approaches to challenge perspectives, expand previous knowledge and misconceptions, and reimagine and explore alternatives, while nurturing their personal motivations towards a sustainable future and its global pursuit:

> … [I]t was just a great program, and provided many perspectives and opportunities for us… [to] expand our own knowledge and… challenge us, but also reinforce us that, "No, we're working towards what we should be [a sustainable future]… in the long run...". (Chloe)

6. Discussion

This study has shared how the program design of a virtual mobility experience (VME) has supported student learning and development as expressed by the students involved. Recognizing the active role of authors in knowledge generation and interpretation (Braun & Clarke, 2019; 2022), and mindful of the inherent limitations in perspectives and study size, the findings underscore that an online environment can foster critical thinking. This program allowed the Australian students to analyze and question the underlying assumptions that inform their perspectives of themselves, their discipline, and the perspectives of others. As a result, students explored, with some students critiquing, how their assumptions shape their understanding of the world, and of science and agriculture - or “our existing ways of thinking, believing, or feeling” (Dirkx et al., 2006, p. 132). This VME allowed for students to actively explore and compare alternative agricultural practices, principles and personal values that broaden their understanding, challenge their assumptions, and help them imagine alternatives in varying ways (Brookfield, 1987). It also allowed for the students involved to broaden students personal understanding, connection, and confidence in relation to science in a meaningful context that supported the foundations in which critical thinking could occur.

The [I]NSPECT Model (Bawden & Packham, 1993) and the use of diverse experts from India and Australia were the ideal catalyst for the real-world context of agriculture and sustainability. By exploring the perspectives from contexts different to their frame of reference and that have real-world implications, students were challenged to consider their assumptions. This enabled them to actively explore, critique and reimagine agriculture. STEM-based OMEs that rely on real-world research or work-based experiences have been shown to develop students’ critical thinking (Bamber & Pike, 2013; Garibay, 2015; Montrose, 2002; Murphy et al., 2019; Oliver, 2015; Sanders & Hirsch, 2014), which is supported by this study. The use of collaboration and peer-to-peer dialogue (making up the majority of time spent online together) further enhanced critical thinking and connection. Students gathered and interpreted a wide range of information and data for their research projects which in turn exposed the students to multiple (and often new) perspectives of agricultural practices and principles with multiple dimensions of sustainability by the people (i.e., their Indian peers, facilitators, and experts) experiencing them first-hand. This helped the students connect to the subject matter as it became personally meaningful (James & Brookfield, 2014). Reflection and social activities, both verbal and written, promoted an awareness of students’ own cultural biases and misconceptions, making the experience more impactful for some. These findings support the ideals put forward by Davidson et al. (2021)

and Sarkar et al. (2019) that science students must be able to think critically to interpret information from a wide range of disciplines and perspectives, and actively and ethically connect with the world around them to respond to global sustainability challenges.

These core elements of the program design - collaborative research, reflection, and intercultural dialogue - also challenged the students' perception of their discipline of science. The program's immersive and intercultural learning activities also provided an opportunity for students to challenge, explore, question, and critique their own thinking outside of their usual frameworks - their home context and disciplinary context (Brookfield, 1987; Santos, 2017). The inclusion of experts from both countries grounded and contextualized the information in new realities. Exposing students to alternate practices or ways of doing science that were enhanced by the cultural layer added to this VME. These findings support the claims found by Guest et al. (2006), Roberts et al. (2018, 2019), and more recently Tran et al. (2021, 2022) that exploring science – how it is understood and practiced – in different cultural and geographic contexts can be beneficial in fostering critical thinking. Like research undertaken by Roberts et al. (2018, 2019) and McLaughlin and Johnson (2014), reflection was incorporated as an intentional aspect of program design. Learning journals and group debriefings supported students to question their own values, misconceptions, and assumptions, leading to a deeper understanding of their discipline and its broader applications in the world in a more significant way.

The findings also show that critical thinking enabled students to question assumptions, analyze and critique information, and explore new and different perspectives, which are crucial for developing a global mindset and intercultural capabilities (Rubin & Guth, 2022; Scharoun, 2015). This VME encouraged critical thinking by facilitating interaction with diverse groups of people, ideas, frameworks, and places. This exposure broadened students' worldviews and challenged pre-existing biases, catalyzing a shift towards critical thinking. Using different frameworks such as [I]NSPECT Model and the Sustainable Development Goals enabled students to consider sustainability, its challenges and solutions, not as isolated approaches, but as complex, interlinked notions requiring multidisciplinary and intercultural thinking and action. This finding challenges the definition put forward that critical thinkers in science can solely solve problems and make informed decisions based on reasoning and logic through the application of scientific principles, methods, and technologies (Wilson, 2017; Santos, 2017). Current global sustainability challenges necessitate innovative, ethical, and creative solutions, distinct from traditional problem-solving approaches (Davidson et al., 2021). This means acknowledging there are no easy or one-size-fits-all solutions as recognized by the students in this VME. This program highlighted to students that real-world situations and solutions are multifaceted, complex, and messy. Of particular influence was the comparison between countries to cultural connection to agriculture, the complexity of incorporating technologies for livelihoods, and the application of science and technology in the field. As such incorporating VMEs, like this study, in STEM education where the goal is to foster a generation of scientists who can navigate collaborative exploration, think critically to interpret information from multiple perspectives, and actively and justly connect with the world around them to respond to global challenges has value (Davidson et al., 2021; Rubin & Guth, 2022; Sarkar et al., 2019).

Overall, the findings of this research support previous research and highlight that student learning and development can occur through the intentional design of an online program (Paradise et al., 2022; Towsin & Walsh, 2016). Critical thinking in the case of this VME also occurred without the need to travel. As Rubin and Guth (2022) point out VMEs do not "happen by virtue of getting people in different countries together in a Zoom room… [it] must be carefully designed and facilitated in order for students to achieve intercultural and disciplinary learning outcomes." (p. 58). By focusing on the experiential design of this program through co-design, the VME fostered students' thinking, expanded their contextual awareness of agriculture and sustainability, supported their confidence, self-efficiency, and connection, and challenged their views and values, resulting in a deeper understanding and appreciation of India, sustainability, science, agriculture and envisioning of a sustainable future for all. While there is no way to know if this thinking will persist beyond this VME, or be put into action, the results do provide some hopeful indicators of future thinking and action by the students involved, particularly concerning their career decisions.

7. Conclusion and Next Steps

Critical thinking – in addition to creativity, problem solving, ethical reasoning and intercultural appreciation - has emerged as a key student capability within higher education in recent years (Hardiman et al., 2022; Vermeulen et al., 2024). Recognizing the STEM disciplines' vital role in responding to emerging global sustainability challenges that are complex and interconnected, we are required to prepare students who have the potential to think and act differently. This requires transdisciplinary approaches as well as intercultural solutions and action. Exploring agriculture more broadly than just a techno-science point of view within this VME provided an ideal foundation to foster critical thinking. For these science students utilizing collaborative research, reflection, and intercultural interaction and dialogue in an online environment was particularly useful in achieving the critical thinking objectives of the program. Students gained a deeper contextual awareness of the diversity of values, social structures and scientific practices that exist in the world, which informs our ways of thinking and doing (Brookfield, 1987).

Although this VME was deemed a success, consideration needs to be given to a few key areas for future programs. As other authors have found (McLaughlin & Johnson, 2006) students can be reticent to complete reflective journals, even when linked to program assessment, as they are not often subject to scrutiny by facilitators or peers. In this study, it was difficult to consider the impact of learning journals on promoting critical thinking as not all entries were completed by participating students. Future iterations of this VME would include individual written journal entries as part of the structured reflective group debriefs (Winchester-Seeto & Rowe, 2019). The online environment was not without its challenges - differences in time zones, language barriers, maintaining student participation, and access to reliable technology to name a few. The orientation session and ongoing communication (via the e-learning platform) were a vital part of ensuring that these challenges did not have a negative impact on learning. Gothard et al. (2011) also emphasize the importance of incorporating departure and re-entry activities as a core part of the program which were embedded as part of the weekly schedule. The resources and time required by the program facilitators to ensure delivery of the program required a demanding level of preparation (and funding), a responsibility shared amongst the bi-lateral team of five facilitators. This was also important in ensuring the continuity of the program. It is hoped by sharing the insights of the program design and the experience of the Australian student participants that future practitioners designing programs similar to the one detailed in this paper may gain valuable direction. It is also hoped that it may increase the representation of STEM, particularly science, in these types of experiences that go beyond just disciplinary outcomes and enable students to navigate new horizons in a changing and complex world.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics Approval

This study has been approved by the Human Research Ethics Committee (HREC) at Western Sydney University, Australia. This HREC is constituted and operates in accordance with the National Statement on Ethical Conduct in Human Research 2007 (Updated 2018).

Note to Users

The authors would be grateful for any information regarding the implementation or adaptation of our work. If you have utilized, reworked, or found inspiration from our program design and scaffolded research tasks (see Supplemental Materials), please email the lead researcher at b.vermeulen@westernsydney.edu.au. We thank you for considering our request.

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Supplemental Materials

Scaffolded Research Tasks for Critical Thinking Development using the [I]NSPECT Model

Week 1: Task 1 (Topic selection) required the students to get to know each other and initiate their project. Students were given prompt questions including their background and interests. They were asked to select one agricultural product that interested the group and that has relevance to Australia and India and were provided with some examples. This activity was an attempt to establish familiarity and online socialisation and navigate intercultural communication while giving the students a chance to activate their interest in the virtual research project.

Week 2 – 3: Task 2 ([I]NSPECT'ing your topic) asked students to interrogate their farming product through the [I]NSPECT model. Students were asked to firstly, as individuals, identify 3 - 5 key influences of their selected agricultural product for each of the six [I]NSPECT domains. Together, the student then took turns discussing and sharing their findings and collaboratively writing one comprehensive list that summarised their collective views. Purposefully, this task required students to adopt different viewpoints, to critically think about their farming product, such as acknowledging differences and similarities between countries.

Week 4 – 5: Task 3 (Diving deeper on [I]NSPECT) moved students toward a deeper appreciation of the complexity of sustainability. Students were asked to select two of the six [I]NSPECT domains that interested the group for further exploration. This task required them students to investigate in detail their farming product, drawing comparisons and contrasts across countries and domains; to examine and discuss with their team members various points of view; and to research the topic widely. Student teams were mixed (two teams per breakout room) to share their findings with one another and identify gaps or synergies between their research projects.

Week 6 – 8: Task 4 (Collating your research) required the students to work together to collate their research and work together to produce a written summary, group reflection and short group video presentation in response to the research question: 'How does the farming product you selected to research compare or contrast between countries across the domains selected?'. Students combined their research findings from Tasks 1-3 to respond and were required to link back to the SDGs and provide recommendations.

Author Biography

Brittany Vermeulen is a PhD candidate and full-time staff member at Western Sydney University working in the field of Sustainability Education. Her current doctoral research interest is centred around the intersection of sustainability, science education and student learning in higher education. Her thesis is a mixed-methods study looking at varying approaches to STEM-based outbound student mobility within Australian universities.

Dr. Jenny Pizzica is an honorary Senior Lecturer at Western Sydney University, Australia. She has over twenty years' experience in academic development and designing and coordinating graduate programs in higher education. She is the recipient of an Australian Award for University Teaching (Team Citation). She has held academic appointments at University of Technology Sydney, Sydney University, and the University of Notre Dame Australia. Her research focuses on academic practices, and higher education learning and teaching.

Dr. Adrian Renshaw has diverse scientific interests, predominately biological and has taught in forensics, environmental, ecology, conservation, botany and more recently animal science. He has 30 years of teaching experience across numerous courses and programs at the university. He has work with the WHO and the Australian government in Indigenous programs and CSIRO school teaching programs. He has won both institutional and Australian National awards for his teaching.

Dr. Jason Reynolds is an earth scientist and senior lecturer at Western Sydney University. Jason's work explores transdisciplinary approaches to environmental challenges. He is a Fellow of the Higher Education Academy and is focused on improving the outbound mobility experience for higher education students.