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Re-orientating experiences: Considerations for student development through virtual mobility in STEM

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Abstract

Outbound mobility experiences (OMEs) provide a catalyst for learning environments that foster student development to occur in a global context. In STEM, OMEs foster critical thinking, creativity and scientific literacy. However, the sudden disruption to international travel due to the recent global pandemic has seen countries worldwide plunged into lockdown and borders closed. While the shift to online learning has been challenging, it has also provided the higher education sector an opportunity for wider implementation of online experiential learning environments, such as virtual mobility. Currently there has been little exploration of the potential of transforming physical, short-term, face-to-face mobility programs to an online environment for undergraduate science, technology, engineering and mathematics (STEM) students. This paper seeks to understand, through existing literature, how we can meet the desired program outcomes of a physical OME to support critical thinking of undergraduate natural science students, when the OME occurs online.

Introduction

Universities play a key role in equipping work-ready graduates with discipline-specific knowledge and capabilities that negotiate the opportunities and challenges brought about by globalization (Villar-Onrubia & Rajpal, 2016; Parrott & Jones, 2018). Further, the importance of developing key capabilities for new graduates has been extensively documented, from the perspective of policymakers to employers, academics, and graduates. In response to this, outbound mobility experiences (OMEs) and international study exchange programs have become a valued part of higher education globally (Bell et al., 2016). The general benefits of international learning experiences are cited as providing opportunities to students who might not otherwise be able to travel, increasing cross-cultural awareness, and supporting student development outcomes in a global context (Tran & Vu, 2018). As such, and emphasized in literature, OMEs provide students with valuable 21st century capabilities necessary for the future of work and are widely promoted by universities for their capacity to develop international career-relevant skills and personal growth (Downey et al., 2012; Adams et al., 2011). Along with this, both policymakers and scholars have become increasingly vocal on the influence of OMEs to further strengthen institutional partnership and connections, and opportunities for public diplomacy between nations (Byrne & Hall, 2013; Hong, 2021; Tran & Vu, 2018).

The reported number of university students undertaking OMEs as part of their degree (e.g. internships, placements, international study tours or short courses) has grown, driven by improved cross-institutional arrangements and increased scholarship opportunities (e.g. the New Colombo Plan, Erasmus+, and U.S. Study Abroad). In 2018, it is estimated that 5.6 million university students worldwide undertook some kind of learning experience overseas, more than twice the number of students in 2005 (Organisation for Economic Cooperation and Development, 2021).

Short-term OMEs have increased in popularity within higher education, with "fewer and fewer students are willing or in fact able to spend an entire term, semester, or year abroad" (Spencer & Tuma, 2002, p. xvi). These shorter length programs, in some countries, make up the great majority of experiences offered to university students, and are greatly an undergraduate phenomenon. For example, two-thirds of mobility experiences for Australian and U.S university students, and one-fifth of experiences for UK university students were short-term (less than a semester) in 2018–19 (Department Education, Skills and Employment, 2021; ICEF Monitor, 2020; Universities UK International, 2021).

While universities have developed many international, domestic, and virtual curriculum student mobility initiatives, periods of border restrictions have accelerated the implementation of such online initiatives. Program coordinators and institutions are being encouraged by funding bodies (e.g. Australia's Department of Foreign Affairs and Trading) to continue to design and deliver their international OME programs to fill this sudden travel gap. Virtual mobility experiences (VMEs), which have also been termed 'Collaborative Online International Learning' or 'virtual exchange', can be defined as a collaborative ICT-enabled, intercultural learning experience that can supplement (i.e. replace) or complement (i.e. pre-trip activity) a physical, face-to-face program (Vriens et al., 2016; Villar-Onrubia & Rajpal, 2016).

There has been limited exploration of physical, short-term, face-to-face OME programs, and even less for delivery in an online environment for undergraduate science, technology, engineering and mathematics (STEM) students. Engaging undergraduate STEM students generally in immersive learning experiences offers a wide range of well-researched benefits; persistence in the discipline, identity to the discipline, increased interest in STEM careers, and increased inclusivity of underrepresented groups (Sanders & Hirsh, 2014; Adkins-Jablonsky et al., 2020; Guest et al., 2006; Garibay, 2015). Learning outside of the classroom in a global context through immersion is a key component that distinguishes mobility from regular classroom-based learning. These immersive mobility experiences are one example of 'learning-by-doing', based on Kolb's experiential learning theory (Doerr, 2013). Immersion in the context of an OME is the combing of the concrete (e.g. travelling overseas) and the abstract (e.g. 'learning' from the experience) in an international location that is geographically and culturally different in context from the learners' previous experiences (Montrose, 2015). For STEM students, there is often a gap between the objects of scientific study and the lived experience, with little chance to reflect on these (Coker, 2017). An experience-based STEM OME program that includes field work, scientific research or work-based experiences "extends the classroom into the community, and students frequently encounter unfamiliar situations that challenge and contradict their perspectives" (Hatcher & Bringle, 1997, p.156). These immersive and experiential mobility experiences actively create space for learning and development in a global context.

While international experiences through physical OMEs have been shown to enhance critical thinking, creativity and scientific literacies of STEM students (Sanders & Hirsch, 2014), this paper seeks to understand, using existing literatute, how virtual mobility experiences (VMEs) in an online space can support critical thinking of undergraduate natural science students.

A review of literature

A literature review of STEM-based learing experiences in higher education was conducted in an attempt to understand critical thinking development in natural science students. This paper draws from global examples of physical (OMEs) and virtual (VMEs) experiences and programs, and the experiential learning pedagogies and tools used to support them.

STEM student learning and development

Education and research in the fields of science, technology, engineering, and mathematics (STEM) are being acknowledged around the world as core to national development, economic competitiveness, and societal wellbeing (Freeman et al., 2019). Traditionally the purpose of a science degree has been to induct students into the discipline. However, in line with this global shift the changing nature of the practice of science poses a new challenge for educators (Rodrigues et al., 2007). STEM students and graduates are now expected to be able to think critically and analytically to interpret information from a wide range of disciplines, and to actively and ethically connect with the world around them by sharing knowledge and problem-solving resolution of social and environmental challenges (Davidson et al., 2021; Sarkar et al., 2019).

While the definition of critical thinking is highly contested among researchers, in science education it is framed around the idea that critical thinkers can solve problems and can make informed decisions based on reasoning and logic through the application of scientific principles, methods and technologies (Wilson et al., 2017). In the natural sciences, critical thinking is the ability to generate knowledge and draw conclusions about the natural world based on facts and evidence (Viterbo, 2021). It connects the learning activities of identifying, developing and critically evaluating ideas and information supported by active pedagogical approaches – specifically, in this case outbound mobility.

Using active inquiry-based pedagogies in OMEs offers the potential for significant student learning through experiential approaches (Ash & Clayton, 2009; Rayner et al., 2013). While researchers argue that for program coordinators facilitating and assessing student learning can be challenging, according to Montrose (2002), in the context of experiential learning, transforming a mobility program into a valuable learning experience for students is via the students' critical analysis of the activities and not merely the activities themselves.

Outbound mobility supporting STEM student learning and development: An unrestricted environment

Outbound mobility is a key mechanism to internationalising curriculum, supporting cultural immersion, innovating curriculum delivery, and nurturing student outcomes in higher education. With the world becoming increasingly connected, it is becoming necessary for students and graduates in all disciplines to understand other countries, cultures and people (Fox & Hundley, 2011). The term outbound mobility experience (OME) encompasses a physical overseas learning activity, whereby students "remain enrolled at their home institution while travelling abroad for a component of their home degree" (Potts, 2015, p. 4). There are a range of different physical international short-term, semester-based and yearlong OMEs available to university students across all levels of study (Table 1). As universities work to make OMEs more accessible, affordable and less complicated, more students are undertaking global learning experiences outside the traditional classroom setting (Harrison & Potts, 2016). This offers higher education institutes a space to design immersive global experiences that support student learning and development.

Table 1. Types of outbound mobility experiences available to university students across all disciplines of study, including STEM.

OME Program Types	Examples of Student Experiences
Faculty-led tours	• Thematic short-term study tours (including industry-relevant programs) • Field-based/lab immersion programs • Cultural immersion programs • Volunteering/community engagement programs • Conferences and summits (undergraduate)
Study	• Overseas short-courses or units of study • In-country language programs • Student exchange programs • Postgraduate coursework
Work-based experiences	• Internships • Practicums • Clinical placements
Research	• Research-related programs • Conferences and summits (postgraduate)

Literature demonstrates that short-term physical OMEs have the potential to construct learning environments that foster student learning and development broadly. Importantly, this environment is arguably created through a series of well-planned, structured program designs. Townsin and Walsh (2016) highlight that learning and development is not gained by traveling overseas but nurtured through a series of planned and considered educational tools and learning activities before, during and after a mobility experience. Strange and Gibson (2017) affirm this by suggesting that "international programs that are designed with experiential learning in mind to include activities that are more hands on, are likely to induce transformation that can have a life-long impact on the learner" (p. 86).

Designing a STEM mobility program that includes real-world research, projects or work-based experiences adds a meaningful layer to the students' immersive travel experience and has been shown to help students develop key capabilities, including critical thinking, creativity, problem solving, scientific literacy and scientific identity (Bamber & Pike, 2013; Murphy et al., 2019; Oliver, 2015; Sanders & Hirsch, 2014; Townsin & Walsh, 2016). Notably, McLaughlin and Johnson (2006) found learning gains in their short-term OME – including critical thinking – in the majority of participating students (60 of 62 students) as evident in the students' final assessment. In their study, students undertaking a biology program participated in a short-term OME engaging with basic hands-on environmental and conservation field research tasks, visiting several field stations and diverse natural areas. Part of the program's focus was for students to think critically about complex conservation issues. The program structure, which included pre-trip preparation, the mobility experience itself, and post-trip analysis, was purposefully designed to facilitate critical thinking and illustrate the scientific process of inquiry in action. These learning activities were supplemented with group discussions, peer presentations, and student observation (reflective) journals to enhance student learning and development.

Utilizing experiential program design is central to cultivating learning environments for critical thinking. For STEM, and in this context of OMEs, it is the critical questioning and analysis of the learning activities designed and engaged with, situated in the real-world, that plays a key role in critical thinking development (Montrose, 2002). For example, reflection – a key part of the Kolb's experiential learning cycle – and reflective activities have been found to foster students' critical thinking. Cai and Sankarana (2015) looked at a short-term OME program to China, which included environmental science students, targeting the development of students' critical thinking skills. Through theme-based interdisciplinary curriculum, supported by cultural immersion activities and experiential program design, relying on reflection, there was evidence of enhanced critical thinking. Formative and summative evaluations of student learning captured growth in students' global awareness, critical thinking skills in analysing issues, and decision making through social and cultural perspectives applied to real-world problems. However, it was cited that critical thinking outcomes were, not surprisingly, distinctive to the individual learner, and not achieved by all students. In another OME program, Roberts et al. (2018) engaged interdisciplinary science undergraduate students including agriculture, plant science and microbiology majors in a short-term OME. The purpose of the OME was to explore the impacts of critical thinking using reflective journaling while abroad in Central America through investigation of agriculture or natural resources-related issues. Thematic analysis of the students' journal entries highlighted that students showed growth in only three of the five categories of critical thinking skills in accordance with Facione's 1990 'Critical Thinking Delphi Report'. Of concern, students lacked evaluation and explanation skills which relate to evidence of reasoning – a key part of the definition of critical thinking in science education. While including reflective activities in the design of a program provides space for STEM students to foster critical thinking, it does not always achieve such a result.

Different places and people, inherent to the design of an OME program, has also demonstrated an influence on critical thinking through global contexts. OMEs involve students travelling internationally, often to unfamiliar destinations or potentially overseas for the first time, to experience unfamiliar environments, lifestyles and cultures. OMEs allow STEM students to understand the similarities and differences between science in different cultural and geographic contexts (Guest et al., 2006).

Tran et al. (2021) found that observing different 'ways of doing science' aided the development of critical thinking in students. A group of Australian undergraduate marine science students participated in a short-term OME to Japan which included edu-tourism activities and language training. In this study, the students' experiential learning opportunities were situated within the distinctive Japanese setting, which was vastly different from the students home (Australian) context. While key objectives of the program were to build and enhance networks between the students and universities, the program also aimed to support discipline-specific outcomes. These outcomes include improved communication and teamwork, enhanced digital literacy, problem-solving skills, global citizenship, and critical thinking. Interviews with students' post-trip highlighted that the experience provided opportunities to strengthen their application of knowledge and changed their perspectives of science through real-world encounters.

While critical thinking development appears to be achievable at varying levels in a physical OME for the majority of students, the question remains if a virtual mobility experience (VME) has the potential to meet the same desired student outcome.

Virtual mobility supporting STEM student learning and development: An environment of travel restrictions

The COVID-19 global pandemic triggered an unforeseen disruption to student mobility – a threat that is not isolated. It is expected that wider global events – increasing climate change-related disasters, worsening modern conflict, and rising conscious consumerism – will continue to be disruptive on global travel (Grahame-Clark, 2020), potentially threatening OMEs. While students have experienced significant impacts, data collected by Australia Education and Career Consultants (AECC Global) found that of more than 3,000 students surveyed almost three-quarters of respondents stated they had postponed or revised their mobility plans, with only a very minor proportion (5%) saying they had completely abandoned the idea (Ross, 2021). While higher education institutions have postponed some of their mobility programs, others have accelerated the implementation of virtual mobility experiences (VMEs) to continue student mobility and improve inclusivity. The physical act of travel has also a major barrier for higher education for many dacades, with the large population of university students being non-mobile (Vriens et al., 2016). Less than 1 percent of enrolled students in the U.S participated in an international experience in 2019–2020, compared to 25 percent of Australian undergraduate students for the same period (U.S. Department of Education National Center for Education Statistics, 2020; Department Education, Skills and Employment, 2021). As such, VMEs can offer a more inclusive learning environment for the great majority of non-mobile students who would otherwise miss out on an international experience.

Student appetite for these types of online programs is also evident. Another recent Australian study revealed that 38 percent of students were open to virtual mobility experiences, a jump from 14 percent the year prior (Study Move, 2021). The study also revealed that students favoured different types of VMEs. The great majority of responding students would consider participating in a virtual internship (40%) over a virtual short course (16%) or a virtual cultural or language program (7%) (Study Move, 2021).

Leveraging and transforming existing work-based OMEs to an online environment has already demonstrated the potential to meet a range of desired student outcomes.

Currently, work-based experiences (e.g. internships) are heavily used by Engineering and Information Technology STEM disciplines (Edwards et al., 2015), and are largely already available to these students in the physical and virtual mobility space through third-party providers. Less opportunities are available to natural and physical science and mathematics students. The application of virtual research projects in place of physical activities could be considered as an additional type of learning opportunity for potential exploration and utilization for natural sciences. Fieldwork in a natural setting for this discipline has been shown to enhance critical thinking, as well as problem-solving capabilities and self-confidence of natural science students (Lei, 2010). It has been demonstrated that the design of an OMEs in the natural sciences typically rely on real-world, experiential learning activities. Enacting this in a virtual space can be supported by online experiential learning approaches. This allows students to gain knowledge and capabilities through meaningful virtual experiences based on real-world examples, while exploring and reflecting through online sharing and collaboration (Vriens et al., 2016).

Studies have highlighted that VMEs can also achieve learning and development for STEM students generally. As highlighted by Villar-Onrubia and Rajpal (2016), STEM-based virtual learning activities intertwined with intercultural collaboration and dialogue, which lend themselves to both OMEs and VMEs, have been shown to create a space for professional practice. In a collaborative virtual project between two universities, UK students worked online with students in China to improve the design of an existing highway junction. While students gained practical experience, producing a project report and presentation delivered to industry professionals, the aim of the program was designed to develop the students' understanding of cultural diversity in team-based engineering professional practice (Villar-Onrubia & Rajpal, 2016). This desired outcome was reportedly achieved.

There is, however, little available literature that demonstrates the application of VMEs for undergraduate natural science students, and even less on these experiences' potential to develop critical thinking capabilities. Other applied disciplines have found evidence to support critical thinking development through VMEs program design. Notably, a U.S university adopted a VMEs as a pre-trip activity for a physical program. The program aimed to develop students' global capabilities, observing critical thinking as a result. Sports-science students engaged in an 8-month online program before a short-term physical trip to Thailand focused on social change through adaptive sport. Reflections captured through assessment tasks found evidence of critical thinking. Duffy et al. (2020) found that critical thinking was "derived from the "process" [being immersed] not the "products" (i.e., the assessments)" (p. 10). The interwoven dynamics of the desired global capabilities (cross-cultural communication, and a sense of global awareness and mindfulness) provided a catalyse for critical thinking. It is thought that the intercultural interactions facilitated online have potential for developing critical thinking skills as students made comments about "recognising different power dynamics, debunking assumptions, and the trial-and-error process of figuring out how to communicate more effectively" with their Thai counterparts (Duffy et al., 2020, p. 10). The design of the program allowed for reflection which aided and fostered critical thinking.

For some academics in STEM a fully virtual approach "does not necessitate the loss of experiential learning in the field" (Lashley & McCleery, 2020, p. 12617). As such, natural sciences, and other applied disciplines, are adopting a blended model. In some instances, the physical aspects occur locally through short-term domestic experiences away from campus. For example, Lashley and McCleery (2020) presented a blended concept for field-based experiences in a whole-of-unit approach for ecology and evolutionary biology curriculum. The authors redesigned two courses that involve a "flipped classroom pedagogical approach that has a synchronous, asynchronous, and intensive laboratory experience sections of the course" (p. 12615) as a COVID-19 response. They found this blended delivery, whereby content was delivered online coupled with intensive localised field activities, created an effective model that retained the benefits of learning in the field for natural science students and supported student development. However, the specific capabilities developed were not defined.

Other researchers have focused on discussing online tools that can be used to foster critical thinking in a virtual space. For example, McLaughlin and Munsell (2015) indicates the use of multimedia in their online modules, namely 'CHANCE', provided high school and undergraduate science students with a "representation of cutting-edge scientific research" (p. 5). These online tools – animations, videos and virtual experiences – allow for engagement through inquiry and give space for students to "explore, critically think about, and understand key environmental science issues and biological concepts." (McLaughlin & Munsell, 2015, p. 5). Using real science data and information, project outcomes suggest that the module allowed students to develop their critical thinking capabilities by exploring, observing, questioning, hypothesizing and analysing. In another study, Thompson et al. (2003) developed a VME program using interactive online scenarios and role play for advertising students. The design of the program aimed to improve students' critical thinking and problem-solving capabilities observing real-world issues. The students took on a virtual role (character) during the interactions. To support this, they interviewed various experts to gain a deeper understanding of the issues, sharing their perspective with the online class. While the outcomes of their project were not provided, they confidently anticipated that the program design would foster critical thinking – "students will exhibit higher-level critical thinking skills and more creative resolutions to various problems after participating in the 'virtual exchange' [VME]" (Thompson et al., 2003, p. 189).

Conclusion and next steps

If we consider the growing need to respond to the impacts of our world's increasing social and environmental challenges and STEM's role in this, critical thinking capabilities are strongly required by science students and graduates. Mobility experiences have been shown to have the potential to develop key 21st century student capabilities, including critical thinking, in both physical (OME) and virtual (VME) settings. While there is a critique around the measuring and assessing of student learning, generally studies have highlighted that the development of students' critical thinking is more than likely achieved through reflection and at times as an unexpected by-product of other structured activities and interactions. It is also evident that the design of the experience, whether it is physical or virtual, plays a role in the development of capabilities and utilizing experiential learning design is core to this. Engaging undergraduate STEM students generally in immersive learning experiences offers a wide range of well researched benefits. These benefits include critical thinking.

To date there has been little exploration of the potential of transforming (or reorienting) physical, short-term, face-to-face OME programs for delivery in an online environment (i.e. a VME) for undergraduate natural science students. Fieldwork in a natural setting for the natural science discipline has been shown to enhance critical thinking, as well as problem-solving capabilities and self-confidence of natural science students – which has been drawn upon in OME litertature. Drawing on existing VME literature from various other applied fields shows that engaging students using real–world material – whether that is scientific data, virtual scenarios or online discussion, with supplementary e-learning materials – has also been shown to have potential to foster critical thinking in students. This could also have applications in natural science. Repeatedly it has been shown that reflection and dialogue aid this process and needs to be included as a core part of the program design where the intention is to foster critical thinking.

While VMEs do not replace the true contextual experience, and often discomfort, of travelling overseas (e.g. sights, smells, sounds, food, unplanned interactions or incidents) that can be transformative for students, they do provide a potential option to enrich student learning and development from home in the current and potential future travel impacts we are experiencing. Further, VME programs offer a more inclusive learning environment for the great majority of non-mobile students who would miss out on an international experience otherwise. The ideas presented in this paper will be further explored. That being, STEM student learning and development through an online experiential VME for undergraduate natural science students, and further to provide access opportunities for non-mobile students and offer immersive learning experiences in circumstances where international travel is restricted once again.

Ethical statement

This study has been approved by the Human Research Ethics Committee (HREC) at Western Sydney University. The ethics reference number is: H14388. This HREC constituted and operates in accordance with the National Statement on Ethical Conduct in Human Research 2007 (Updated 2018).

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