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2 **Incorporating science communication and bicultural**
3 **knowledge in teaching a blended volcanology course**

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14 **Abstract.** A variety of skills can be taught alongside course content. In the University of Canterbury third-year
15 ~~university~~ course on magmatic systems and volcanology, we chose to focus on teaching bicultural competence
16 and science communication while transforming the course to a more skills-based, flexible, flipped classroom
17 model. We document the development process and measure student perceptions associated with these skills. We
18 used two edX massive open online volcanology courses (MOOCs) as ~~flexible~~ skills-focussed learning resources
19 to replace lectures and supplement hands-on laboratory and tutorial sessions to teach volcanology.
20 We compare the ~~flexible~~ skills-focussed courses with baseline data from 2021, gathered during an initial iteration
21 of the course which included interactive volcanology lectures, and an online Iceland virtual fieldtrip component.
22 The new ~~skills focussed~~ course was developed using the original 2021 ~~interactive online~~ Iceland virtual fieldtrip
23 to create the two virtual fieldtrip-based MOOCs with new bicultural and science communication components. To
24 achieve this, we used cultural advisors from connections through NZ research programs and kaiārahi (Māori
25 learning advisors) from the University of Canterbury. In the course, these experts ensured appropriate cultural
26 guidance at specific volcanic sites and appropriate assessments. Mātauranga (Māori knowledge) of volcanoes is
27 included and taught by video of kōrero (oral knowledge) from members of ~~local~~ mana whenua (tribes local to the
28 volcanoes) in the areas that are visited in the course.
29 In this paper we describe the development of a flipped classroom MOOC featuring bicultural competence and
30 science communication skills, and we report students' reflections on learning with a focus on ~~bicultural~~
31 ~~competence and science communication. these featured points.~~ We analyse student reflections and comments from
32 the two iterations of the online content by specifically coding for comments regarding skills learnt. Student
33 responses to the reflective question *What did you learn in this course and why is it important to you and/or your*
34 *potential career?* ~~showed show~~ a marked shift. ~~Compared to 2021, in~~ between the years. In the new 2022 course,
35 students' reflections were more likely to highlight a skill rather than content, and there was a large increase in
36 students who reported science communication or bicultural competence as a potential skill that would be useful
37 to them. Student quotes from throughout the course and in response to the reflective question ~~Has this course~~
38 *influenced your bicultural competence?* are used to explore how and why these skills were valued by the students.
39 These courses provide a freely available and potentially flexible model to teach bicultural and science
40 communication skills alongside volcanology.

41 **1 Introduction.**

42 Geoscience instructors teach content and skills in a variety of settings, e.g., lectures, laboratories, online modules,
43 projects, and in person and virtual field experiences. To learn and master new skills students need to employ
44 adaptive expertise techniques (Bohle Carbonell et al., 2016) and distributed practice (Benjamin & Tullis, 2010)
45 by practicing skills multiple times and in different scenarios. Bicultural confidence is a valued skill in Aotearoa
46 New Zealand¹, and cultural confidence and competence is important globally and inherently linked to sense of
47 place, a key concept in the geosciences (Apple et al., 2014). However, cultural competence is rarely taught in
48 geoscience courses (Mosher and Keane, 2021). Here, we present how we integrated a new skills-based learning
49 goal (including bicultural confidence) into the course. This additional learning goal was introduced and assessed
50 in a 3rd year volcanology course using two massive online open courses (MOOCs) using and a flipped classroom
51 model. Here, we define flipped classroom in our context as a teaching format where the majority of the content is

transferred outside of scheduled class time via an interactive MOOC, and face to face time is used following this content for consolidating knowledge and reflecting on learning during workshops and labs.

Teaching and learning about volcanoes is of public and professional interest, particularly in countries with significant volcanic risk like Aotearoa New Zealand¹. MOOCs are a method where both public, professional, and institutional audiences can be reached (Rodrigues-Silva & Alsina, 2024) and skills important to become effective volcanologists can be taught. Flipped classrooms provide a scenario where content is delivered outside the classroom at students' own time and pace, and that "homework" is turned into more active learning that takes place in the classroom (Bergmann and Sams 2012), although the flipped model is variably applied and assessed (Kapur et al., 2022). Where flipped classrooms are combined with interactive online material (Wang and Zhu, 2019, Forbes et al., 2023), students can be given opportunities for adaptive expertise and distributed practice using workshops and laboratories where feedback and reflection are used to cement learning of skills. However, both MOOCs and Flipped classrooms have challenges. MOOCs have low completion rates and frequently lack meaningful peer and instructor interaction (Khalil, H. & Ebner, M. 2014, Kurtz et al 2023), in contrast flipped classrooms frequently require very high levels of "buy in" from both instructors and students (Collopy & Arnold 2009). Studies where MOOCs and flipped classrooms are combined report some benefits over the stand-alone models (Ghadiri et al., 2013).

The aims of the study are to (1) describe the development of a flipped classroom MOOC targeting bicultural competence and science communication skills, (2) report students' reflections on learning in 2021, and 2022, by coding reflections for comments relating to bicultural competence and science communication. (3) Discuss how the students' reflections relate to specific course developments by comparing the findings from 2021 and 2022 student reflections and focus groups.

2 Literature context.

2.1 Geoscience Skills.

Volcanology courses exist as part of a geoscience program where course development, such as introducing new skills, is achieved by mapping knowledge, skills and attitudes across courses to ensure graduate learning objectives are met that service the geoscience workforce (e.g., Mosher and Keane 2021). The required skills from geoscience employers are communicated to faculties and professional bodies via research on job advertisements (Shafer et al., 2023), focus groups (Nyarko and Petcovic, 2022), and working groups with academics (Mosher and Keane, 2021). These studies show the skills most valued by employers; specifically writing, field and data collection, planning, communication, teamwork and interpersonal skills. Therefore, it is important to consider which of these skills are currently being taught within the curriculum (Keane et al., 2022⁺; Mosher et al., 2014; Viskupic et al., 2021), so we can identify the skill deficits that need to be taught.

A general survey of the workforce highlighted geoscience skills within geoscience courses at undergraduate geoscience programs (Viskupic et al., 2021). The survey reported that geoscience skills (e.g. rock description), data skills, and communication skills were commonly practiced across many courses, although it should be noted that the communication skills reported were around communicating with peers and the instructor, and not specifically relating to communicating with the public or those outside of geosciences. Complementary to this, a status of geoscience graduates report (Keane et al., 2022⁺) highlighted three areas for improvement amongst our

90 geology graduate students: 1. working across cultures; and 2. Communicating with the public; and 3. Working in
91 interdisciplinary teams. This report, coupled with ongoing curriculum reform at the University of Canterbury,
92 provided motivation to develop, implement and research the integration of these skills within an existing 3rd year
93 volcanology course.

94 A range of practice-oriented, authentic, and/or work integrated tasks and assessments have been shown to be
95 effective at developing graduate attributes in education and nursing (Gulikers et al. 2004; Karunanayaka and
96 Naidu, 2021). These tasks range from work placements, fieldtrips, and simulations, to practice oriented or
97 authentic assessments (Kaider et al. 2017). Work placements and fieldtrips have been shown to be effective
98 authentic experiences aligning with desired skills (Miller and Konstantinou, 2022), but they are also time and
99 resource intensive, expensive, and not always equitable experiences (Kaider et al., 2017). Simulations and virtual
100 fieldtrips have been used which can be particularly affective when coupled with authentic assessment to augment,
101 achieve added value, or provide alternatives (Watson et al., 2023).

102 **2.2 Volcanology learning and teaching research.**

103 Recent research into teaching and learning in volcanology provides evidence for research gaps (Dohaney et al.,
104 2022a, 2023b). Volcanological learning and teaching research at a Tertiary level has focussed on research skills,
105 and field skills, followed by volcano monitoring, communication, teamwork and quantitative skills (Dohaney et
106 al., 2023a 2023b). In addition, a gap in research relating to addressing a lack of diversity is becoming increasingly
107 recognised and hence addressing this is a burgeoning area of research in geosciences (Gates et al., 2019; Mogk,
108 2021) and volcanology (Dohaney et al., 2023a; 2023b). Communication skills have been typically taught using
109 role play exercises and simulations (Harpp and Sweeney 2002; Nunn and Braud 2013; Barclay et al. 2011;
110 Teasedale et al. 2015; 2018; Dohaney et al., 2015; 2018) but also incorporated into lectures and labs (Whittecar,
111 2000; Gonzales and Semken, 2006).

112 **2.3 Cultural sensitivity in geoscience education.**

113 As much geoscience is landscape and place focused, it is inherently linked to culture (e.g. sense of place, Apple
114 et al., 2014) and cultural considerations can be crucial when working in the geosciences (Mosher and Keane,
115 2021). Despite this, working across cultures is rarely taught in the geosciences (Mosher and Keane, 2021).
116 Coincidentally, or consequently, diversity is low in geosciences compared to other sciences. Geoscience education
117 needs to be culturally responsive by explicitly centering Indigenous students, addressing racism,
118 Indigenous identity, sovereignty, and data sovereignty (McKinley et al, 2023). Key strategies for
119 indigenous student success are multi-faceted, layered support, underpinned by the principles of respect,
120 relationships, and responsibility (Milne et al, 2016). Successful Earth science curricula for indigenous learners
121 include outdoor education, a place and problem-based structure, and the explicit inclusion of traditional
122 indigenous knowledge. (Riggs, 2005). Despite this, field trips are frequently cited as a barrier to indigenous
123 students, due to family or tribal commitments (recognising this will also impact other field-based disciplines)
124 and/or general insensitivity to traditional knowledge around place, (Marín-Spiotta et al., 2020; Carabjal &
125 Atchison, 2020) and in particular around places to be visited. Similarly, indigenous students face challenges on
126 placement, including racism, discrimination, misrecognition, and misrepresentation, and the importance of
127 relationships for positive experiences (Pallas et al, 2022).

128 A recent study reports that culturally aware teachers, mentors or practitioners are an important factor in students
129 choosing the geosciences as a career (Todd et al., 2023). Appropriately incorporating traditional knowledge and
130 mentors into geoscience curriculum can improve communication and collaboration across disciplines and cultures,
131 and encourage creativity and problem solving (Smythe et al., 2017; 2020). Indigenous research frameworks can
132 enhance higher education by promoting relationality, multilogicality, and promoting equitable practices in
133 research, teaching, mentoring, and organizational leadership for ~~Indigenous~~indigenous students. (Reano, 2020)
134 Recent research in volcanology education has emphasized the use of authentic voices to teach cultural sensitivity
135 and indigenous knowledge across many cultures, particularly where volcanoes hold specific significance (Saha et
136 al., 2021). Cultural competence is an area of educational focus in Aotearoa ~~New Zealand~~NZ, as workplaces are
137 increasingly seeking employees with this skill set as the country strives to draw from all available knowledge,
138 uphold treaty of Waitangi obligations and equitable educational outcomes for Māori and non-Māori. Māori, the
139 ~~Indigenous~~indigenous people of Aotearoa NZ have their own knowledge system (Mātauranga Māori) and part of
140 this are keen observational and generational understandings of their local area and the history of past volcanic
141 activity (Cashman & Cronin, 2008; King et al., 2008; Tapuke et al., 2019). Regrettably, Mātauranga Māori has
142 been either exploited or marginalized in science education (McKinley, 2005; Smith, 2012; Smith and Richie,
143 2013). Historically institutional racism has often attenuated Māori experiences in science education leading to
144 under achievement in traditional measures of learning for Māori students and students from low socio-economic
145 areas (Macfarlane & Macfarlane, 2018). Braiding of Mātauranga Māori with geology can thus lead to increased
146 public preparedness and understanding of these natural processes (Bretton et al., 2018; Gabrielsen et al., 2018;
147 King et al., 2008; Pardo et al., 2015; Swanson, 2008; Tapuke et al., 2019).

148 The teaching of volcanology frequently underutilises indigenous knowledge sources. The new courses described
149 in this paper highlight the importance of weaving indigenous knowledge of areas studied, and the benefits that
150 could come from shared and woven knowledge. This work builds on approaches and relationships outlined and
151 defined in Saha et al. (2021, 2022). Indeed, the bicultural content used in the course in our research was in the
152 form of a virtual fieldtrip, and several videos were reused and repurposed from such previous work, as well as
153 additional videos recorded or sourced.

154 **2.4 MOOCs and flipped classrooms.**

155 The underlying concept of a flipped classroom is that the passive component of learning, the content delivery, is
156 done before class, and the active component of learning, discussion, problem solving and collaboration is done
157 with peers and instructors (Chen, 2016; Tan et al., 2017; Hu et al., 2019; Karagöl and Esen, 2019). ~~Another way~~
158 ~~of putting it that~~ “~~content~~“Content” (reading or videos) is delivered outside the classroom, and “homework”
159 (problem solving with peers and instructors) is done in the classroom (Bergmann and Sams 2012). However,
160 application and assessment of the flipped classroom model is highly variable, and a meta-analysis of data suggests
161 that contrary to the underlying premise, it is not the active learning component of flipped classroom that drive
162 measurable learning effects. Interestingly, the use of an additional lecture after online content shows a significant
163 measurable learning effect (Kapur et al. 2022). Kapur et al. (2022) suggest a Fail (allow students to struggle with
164 a problem), Flip (content delivered), Fix (misconceptions are explored) and Feed (feedback from students and
165 instructors) model. Although this model is yet to be thoroughly tested, it ~~certainly~~ emphasizes the role of allowing
166 students to struggle, before or during content delivery when flipping the classroom.

167 On the other hand, MOOCs are a rapidly growing global phenomenon designed to make education globally
168 accessible and allow students all over the world to learn from the world's best educators. There are many MOOC
169 platforms, and most courses consist of a format of short 3-8 min videos, and a series of questions and discussion
170 boards, variably moderated by instructors and teaching assistants. However, MOOCs have high levels of students
171 not completing courses and students who are disengaged with content. Small open online courses (SOOCs) also
172 exist to address some criticisms of MOOCs, whereby small cohorts can more easily develop meaningful peer and
173 instructor interactions.

174 Massive open online courses (MOOCs) and flipped classrooms can be seen as occupying two end members of the
175 education spectrum in terms of individualised learning. MOOCs are designed to maximise the instructor reach,
176 by making material accessible to a great number of students. Flipped classrooms were suggested as an alternative
177 to the traditional classroom, as a methodology to promote active and tailored learning in classrooms by increasing
178 instructor and student interaction. The learning experience in a MOOC invariably ends up being uniform and less
179 personalised, whereas in a flipped classroom setting learning strives to be as individualised and personal as is
180 practical. In our model, we drew from Māori education pedagogies to merge the advantages of the MOOC and
181 flipped classroom formats. We deliver accessible online MOOC content with novel digital assessments and
182 activities, in addition to face-to-face labs and flipped style workshops with the goal of developing lecturer-student-
183 peer relationships and skill learning through reflection, discussion and connection to online environment. The
184 benefits of working face-to-face and building lecturer-student-peer relationships are well established and highly
185 effective Māori educational pedagogical techniques – kanohi-ki-te-kanohi and whanaungatanga respectively
186 (Kana & Tamatea, 2012, Bishop et al. 2014)

187 The changes to the course discussed and presented here were developed and implemented before and during the
188 context of COVID-19, and at a time when University of Canterbury had recently signed up to become part of
189 global MOOC platform edX. The COVID-19 pandemic has shown a growth in online and blended learning, and
190 with it a growth in the use of MOOCs (Aristovnik ~~A~~, et al. 2023). The post COVID-19 environment has seen a
191 strong global demand for flexible blended courses, providing both flexibility of online content but also providing
192 opportunities for face-to-face interactions when conditions allowed.

193 **3 Study setting and population.**

194 **3.1 Course information.**

195 The course that was the focus of the research is an elective undergraduate 3rd year Volcanology and Magmatic
196 systems course, part of a geology BSc degree at a research university (Watson et al., 2022; 2023). The volcanology
197 component of the course, the focus of this study, was redeveloped in 2022 following successful implementation
198 of an Iceland virtual fieldtrip module (Watson et al 2022; 2023). The Iceland virtual fieldtrip formed the basis for
199 MOOC development on the edX platform.

200 The redevelopment was driven by the instructor and informal conversations with Māori students in earlier
201 iterations of the course, and the realisation that there was a missed opportunity to develop skills relating to science
202 communication in the bicultural context of Aotearoa ~~New Zealand~~NZ. Of relevance is the strategic aims of
203 University of Canterbury towards upholding and uplifting Te Tiriti o Waitangi (The Treaty of Waitangi). This
204 includes the inclusion of Mātauranga Māori (Māori knowledge) and promoting the Bachelor of Science graduate

205 profile of bicultural competence and confidence as essential skills in a multicultural Aotearoa NZ. The course
206 instructor identified improving this outcome of the course as a key goal for this project.

207 The course development was made possible by a University of Canterbury program to foster professional
208 development, scholarship of learning, and leadership (University of Canterbury, 2024). Kennedy and Davidson
209 were provided with Distributed Leadership in Teaching Practice (DLTP) fellowships to explore the use of MOOCs
210 as tools to help flip the classroom at the University of Canterbury to provide flexible learning solutions for
211 students. The fellowships provided resources and time bought out from regular teaching research and admin duties
212 to develop a second MOOC, implement skills focussed assessment, and a model for the university to use MOOCs
213 to deliver online content and facilitate flipping of the classroom.

214 No student demographic data was directly collected for this research. However, we approximate gender
215 proportions from class enrolments and ethnicity from a yearly university-wide survey to provide readers with an
216 approximation of class demographics. In 2021, 48% of students identified as women, 50% of students identified
217 as men and 2 % as gender diverse. In 2022, 57% of enrolled students identified as women and 41% identified as
218 men and 2 % as gender diverse. In the university wide survey, of university students that were in 3rd year geology
219 programs from 2019–2021, 73% of the students were of European descent, 16% of Māori ancestry, 3% were of
220 Asian descent, 3% of Pacific origin and 3% had other unspecified ancestry.

221 It is also worth mentioning the impact of the COVID-19 pandemic on these two study populations. Neither cohort
222 was directly impacted by COVID lockdowns during the implementation of this course, although it is worth noting
223 that the 2022 cohort had a larger proportion of their degree affected by COVID-19, particularly missing out on
224 several face-to-face fieldtrips in other related courses as a result of covid lockdowns during other semesters of
225 their study.

226 **3.2 The development of the course -Learning goals, implementation, and materials.**

227 The course was significantly changed by adopting a flipped classroom MOOC. We used the opportunity offered
228 by these changes to intentionally target bicultural competence and science communication skills. We used a
229 constructive alignment approach ~~based around, a method where we used our course~~ learning goals, to link all
230 assessments (online content, laboratory exercises and workshop questions) ensuring that all learning is tied back
231 to our original desired outcomes for students taking the course. This was additionally motivated by
232 universityUniversity strategy to provide student focussed, flexible, accessible education for all students. In 2021,
233 the course learning goals were as follows:

- 234 1. Realize the importance of igneous rocks in geology and to society.
- 235 2. Identify and classify igneous rocks and their geological environments.
- 236 3. Use geochemistry to explain why magma is generated, diversifies and erupts.
- 237 4. Use geochemical data, thin sections, and maps to reconstruct the magmatic and volcanological histories.
- 238 5. Discuss physical volcanological processes with relevance to magma properties.
- 239 6. Describe volcanic rocks in the field using examples from Iceland and New Zealand.

240
241 In 2022 this new learning goal was added:

242 7. Communicate science with different audiences and appreciate the value of Māori knowledge.

243
244 Baseline data was collected in August-October 2021. During this period, the course consisted of 6 weeks of
245 volcanology content, two interactive 50 min lectures a week (using in class exercises and live multiple-choice
246 quizzes), and a 2.5 hr hands-on laboratory and workbook (Table 1). The last two weeks of the course was devoted
247 to the Iceland Virtual Fieldtrip, an interactive online module and two flipped classroom style workshops-[\(Table](#)
248 [2\)](#). Students wrote a final summative exam during exam week. Course level learning goals focused around
249 observing and explaining volcanic textures, landscapes, and processes, and interpreting eruption mechanisms and
250 histories (Watson et al., 2022,2023). Specific learning goals were outlined in each lecture, laboratory, and online
251 module.

252 The 2022 version of the course underwent a year of redevelopment working with online learning advisors,
253 Mātauranga Māori advisors, and working with a community of practice of other DLTP fellows. Online learning
254 advisors helped us design assessments and exercises that aligned to the learning goals and made use of
255 functionality embedded in the edX online learning environment. ~~Gagné's 9 events of learning (Gagné, 1974) and~~
256 ~~Universal Design for Learning principles guided the design of content and activities, to promote deep~~
257 ~~understanding of the content, skill development and inclusive learning that meets the needs of diverse learners.~~
258 ~~The~~The edX learning environment provided a range of assessment options with functionality that went beyond
259 quiz questions. In addition to designing quiz type of assessments that provided instant feedback to students, we
260 were able to incorporate peer assessment and reflection to promote engagement and learning at higher levels. The
261 platform also enabled a seamless presentation of content in multiple ways such as text, video (including 360
262 video), audio, as well as interactive content for students to interact with in real time (e.g. interactive graphs, virtual
263 simulations, interactive maps).

264 For cultural content and assessment design we worked with cultural and Mātauranga Māori advisors with whom
265 we had strong existing relationships that had been carefully built and supported through research grants. Previous
266 research showed that shared *relations* and *values* were crucial to create *space for sharing* where challenges and
267 emerging understandings could be repositioned (Saha et al., 2022). Through discussion with our cultural and
268 Mātauranga Māori advisors we obtained permission to reuse video segments mostly recorded for other purposes
269 (e.g. Saha et al., 2022). In addition, we worked closely with the Faculty of Science kaiārahi, literally translated as
270 the canoe steerer, but meaning (in this context) a cultural teaching and learning advisor. She helped us embed
271 cultural content and design culturally appropriate assessments to go along with the videos provided by our cultural
272 leaders and Mātauranga Māori advisors. We worked hard to embed the cultural aspects with assessment
273 throughout the course to avoid tokenism, by valuing the content through assessment and reflection.

274 Similar to 2021, the redeveloped course in 2022 consisted of 6 weeks of teaching, however now students were
275 expected to complete weekly 1.5-3 hrs worth of interactive online MOOC virtual fieldtrip work in their own time
276 and attend both a 50 min flipped workshop and 2.5hrs of lab work (Table 1). In lieu of a final exam, students
277 completed an applied science communication project which was handed in during exam week-[\(Fig. 1\)](#). This
278 change in assessment reflected the shift towards achieving the new skills-based learning goals.

279 The lab content and work were identical for both groups, and the learning goals were still focussed around
280 observing, and explaining volcanic rocks and landscapes, and interpreting volcanic histories and mechanisms. As
281 mentioned earlier, the key difference was the additional learning goal introduced into all the online modules and

282 workshops, focussing on the skill of science communication to diverse audiences and around developing bicultural
283 competence. Space to achieve these extra learning goals was made by reducing the number of international
284 examples of volcanoes covered in lectures and by focussing on New Zealand and Iceland only.

285 Both the 2021 and 2022 versions of the course had online content that is interactive, with 360 videos, 3D rocks
286 and 3D landscapes, i.e., active, engaging online volcano science content. 360 videos and virtual rocks and
287 landscapes necessitated students to manipulate 3D space, and most activities have multiple choice, or drag and
288 drop questions with feedback provided for incorrect answers that guide students to think again or re-evaluate their
289 thinking in a particular direction (Table 23).

290 In 2021, the online content was only used during the last 2 weeks of the course. In 2022 the online content was
291 every week, and every module in the 2022 iteration of the course ended with an applied science communication
292 mapping activity. These skills orientated additional activities were introduced in the online content, in the
293 workshops and as an additional question in the laboratory workbooks. Some of the online science communication
294 tools in 2022 version also featured interactive online drawing exercises and peer assessment of other students'
295 answers, with marking rubrics that in most cases assessed cultural considerations (Table 23).

296 In 2022, we developed our flipped workshops (Table 2) to systematically incorporate exemplars of students'
297 online contributions, interactive questions used to promote mental ramp-up for students (Kapur et al, 2022) and
298 added focus on communication skills in the workbook questions and in class discussion. Additionally, in 2022, at
299 the end of each module students were asked to rate how confident they were to achieving learning goals and to
300 justify their responses at the end of each module (Table Fig. 2). This was implemented to guide the workshop part
301 of the course, where the instructor would review the student responses and focus on learning goals where students
302 were less confident. (Fig. 2). Therefore, the workshop consisted of part lecture, which focussed on learning goals
303 where students were less confident and part reapplication and mastery of content in a different context through a
304 question that needed to be answered in a workbook.

305 In summary, the 2021 version of the course, had many elements of active learning in lectures, labs, and online
306 content but lacked the learning goal (7) Communicate science with different audiences and appreciate the value
307 of Māori knowledge. In 2021, only the last two weeks had a form of flipped classroom. In 2022, the class was
308 truly flipped aligning better with recent models of flipping of the classroom (e.g. Kapur et al., 2022), allowing
309 students to fail, and reflect.

310 **4 Methods**

311 The research used qualitative evaluation of students' responses to questions where students were asked to reflect
312 on their learning following a similar methodology to Engel et al., (2022). The study was reviewed and approved
313 by the university's human research ethics committee (Ref: 2021/116).

314 **4.1 Data sources.**

315 We used three different data sources to complete the qualitative evaluation. The first is a student reflection that
316 students completed towards the end of the course. The second data source are focus group interviews that were
317 completed after each course. The third data source are student artifacts from the online part of the course.

318 In both 2021 and 2022, at the beginning of the final laboratory session of the course, students were asked to
319 complete four reflection questions related to their learning in the course. All students were asked to complete this
320 questionnaire as part of their normal coursework. 21 students agreed to participate in the research (and thus share
321 their reflections) in 2021 and 27 students agreed in 2022. This research uses two of these questions as data sources:
322 Q1. What did you learn in this course and why is it important to you and/or your potential career? Q2. Has this
323 course influenced your bicultural competence? (Table 34)

324 The timing of the questionnaire was immediately after the course content, although before most students had
325 completed their projects. This offered the students a tangible and immediate opportunity on which to reflect on
326 whether the course had achieved its intended learning goals. The reflective questionnaire served both as a means
327 for students to consolidate their learning and as a data source for our research questions. Reflective questionnaires
328 and journals are a common method in STEM education research (Boyle et al., 2007; Scott et al., 2019;
329 Treibergs et al., 2022). The first question offered an open-ended opportunity for students to think about what they
330 learnt without being prompted towards thinking about learning goals or specific skills. The second question was
331 targeted towards the specific learning objective of bicultural competence which aligns with a university wide
332 graduate attribute.

333 Focus groups were held after the last week of class both years. The focus group interviewer asked several questions
334 related to the course changes (Supplemental A). The main questions relevant to this research was:

- 335 • How has the course affected the way you feel/think about your bicultural competence and confidence?
- 336 • How has the course affected the way you feel/think about your science communication skills?

337 The focus groups were run after the course had ended but before the final exam or project was completed. 10
338 students participated in 3 focus groups in 2021 and 7 participated in 2 focus groups in 2022.

339 We also used student artifacts from to courses as a source of data. In 2022, at the end of each module students
340 were asked to rate how confident they were to achieving learning goals and justify their responses. These
341 responses, as well as other responses to open ended discussion questions throughout the course, were additionally
342 analysed to explore whether specific part of the course led to perceived improvements in achieving the learning
343 goals relating to communication skills or bicultural competence. 6 end of module questions and 11 discussion
344 questions were analysed.

345 **4.2 Data Analysis method**

346 **4.2.1 Reflection questionnaire**

347 Students' reflection responses were coded by breaking down the two questions into sub-questions to help analysis
348 (Table 34). Each questionnaire was then coded according to these sub questions using coding categories. For
349 example, Question 1 of the questionnaire was simplified down three sub questions "What was learnt?", "Is what
350 you learnt important to your future career?", and "Is what you learnt important to you personally?" (Table 34).
351 Student responses to these questions underwent a first order coding content knowledge, skills or attitudes.
352 An example of how an answer is coded is shown in a response to Question 1 from the questionnaire below.

353 *"This section of the course has taught me heaps! I loved learning more about the different*
354 *types of volcanic eruptions, how they form, and the hazards associated with different*
355 *eruptions. I can see how understanding these fundamental concepts will be valuable going*

356 *forth into a geologist career. As well as learning about geology, this course also*
357 *strengthened my ability to be curious and excited about things and ask questions. It was*
358 *very eye-opening hearing Ben's reflection of the Whakaari disaster, as before hearing his*
359 *perspective I had never considered this implication between science research and human*
360 *safety of a tourist destination."*

361 In this quote, the student stated that they have learnt about content knowledge including different types of volcanic
362 eruptions, how they form, and the hazards associated with different eruptions. They also mention that the course
363 gave them an understanding of fundamental concepts that would be valuable for a geology career. Lastly, they
364 state that the course helped strengthen their curiosity and gave them excitement to ask questions. It also changed
365 their perspective on science research and human safety at a tourist destination such as Whakaari. This answer was
366 marked as a student having gained knowledge of a factoid and changing their attitudes towards learning and
367 thinking. This student did not mention anything about skills gained. This method was utilised for both questions
368 in the questionnaire across all years of this study.

369 **4.2.2 Focus Groups and Discussion boards**

370 Focus groups were recorded and then transcribed. The questions asked during the focus group were formulated to
371 supplement the questions asked in the reflective questionnaires. These questions and their equivalent in the
372 reflective questionnaires are presented in Table 45. The discussion board data was analysed to track if a comment
373 related to biculturalism or science communication. Both the focus group and discussion board data are used to
374 supplement the data from the reflective questionnaires to clarify and drill deeper into the meaning of the data.

375 **5 Results**

376 We report course reflections on learning in 2021, and 2022, relating to learning skills, and specifically code our
377 analysis for bicultural competence and science communication. We also present focus group discussions and
378 specific student reflections within the course that related to either bicultural confidence, science communication
379 or specific pedagogies, activities, or course elements.

380 **5.1 Overall learning**

381 The analysis of student reflections of Q1. *What did you learn in this course, and why is it important to you and/or*
382 *your potential career?"* showed that from 2021 to 2022 there was an increase of 13% of comments on learning
383 that related to skills when compared to learning content or general attitudes (Fig 4.3, Table 34). When these skills
384 were categorized by types of skills, students in 2021 were more likely to mention skills relating to data, or other
385 skills such as microscope skills, whereas in 2022 students specifically mentioned bicultural competence and
386 communication, as well as flexible learning skills (Fig. 2.4).

387 In 2021 studentstudents were more likely to mention content knowledge and other skills relating to the
388 laboratories, for example,

389 *"I learnt different aspects of volcanology and magmas, this is crucial in understanding*
390 *volcanic environments and deposits as well as using microscopes to identify different*
391 *minerals in thin section and understand how this can relate to magmatic environments.*

392 *This could be applied to many careers outside of volcanology, the skills taught in this*
393 *course are essential for any geologist.”*

394 The student mentions that they learnt about different magmas (content knowledge) and using microscopes (Skills).
395 They also address the second part of the question and mention that the skills learnt in the course are applicable to
396 many careers outside geology and are essential for any geologists. Other students’ responses focused on content
397 knowledge and several students and did not mention any benefits to their future career, e.g.:

398 *“The effects of a volcano on the surrounding area in the form of ash and bombs etc.*
399 *different types of magmatic flows and what moves them such as gas content and if they’re*
400 *mainly juvenile etc.”*

401 **5.2 The learning environment**

402 Although the reflection question focused on *what* was learnt, many students mentioned *how* they learnt, and this
403 was coded as a skill in both years analysis. Particularly, the freedom to work at their own pace was commonly
404 mentioned in the reflection exercise:

405 *Helps me be able to go at my own pace, and not having to sit in one spot and watch a 50*
406 *minute straight lecture which is very boring and mentally draining.*

407 *The online modules were a very different way of learning than I was used to, and I think I*
408 *can take lessons of time management, persistence and quizzing from it. I think that my time*
409 *management started poor, but found that when I was able to push through the temptation*
410 *for distraction...I also liked how the online work quizzed me after introducing a topic, and*
411 *I think that this is conducive to my learning*

412 *The modules allowed me to work at my own pace and better understand the material as I*
413 *could go back and re-watch videos or re-attempt an answer if I got it wrong, which helped*
414 *me figure out what I needed to focus on more within the modules and my learning.*

415 *Allowing us to re-attempt the questions and self reflect/mark showed that I learn from*
416 *making mistakes and emerging myself within a topic more which was helpful.*

417 *I have enjoyed the small quiz questions directly underneath the content that introduces*
418 *what the questions will be about, it keeps the knowledge fresh for the questions.*

419 This flexible blended learning environment was seen as a positive development, especially the ability to work at
420 their own pace. Some students identified their own growth in time management skills. The frequent quiz questions
421 associated with content is also mentioned positively several times.

422

423 Overall, after the intervention students identified communication and bicultural competence skills, as well as
424 flexible learning more often in their reflections, with less mention of content knowledge and attitudes.

425 **5.3 Specific aspects of the course linked to learning by students**

426 Student specifically regularly mentioned exercises in a positive manner. Student appreciated the models and maps
427 that were part of the course as per some student reflections (this is consistent with previous studies Watson et al.,
428 (2023):

429 *The online lectures really helped with outcrop descriptions and 3D visualisation. the use*
430 *of models and maps in this course was AMAZING, and I really found they helped my*
431 *understanding of the larger scale geological processes which the course was trying to*
432 *teach us.*

433 Students mentioned the specific assessment exercises, e.g in the reflection at the end of a module, this student
434 mentioned an open answer question that was asked in that module:

435 *It also was directly linked to what we were learning about like with the geothermal*
436 *resource email to the Maori land owner, rather than randomly being brought in every now*
437 *and then unrelated to what was goin on...I also like that there were Maori experts in their*
438 *fields who were directly teaching some of the concepts, that was great.*

439 In the focus groups, students mentioned that they appreciated the guided method used to teach skills through
440 applied exercises:

441 *I think those sorts of yeah[exercises], like none of my other courses have really touched on*
442 *that and having that like guided approach through it and like I think it's definitely a cool*
443 *skill that I have like obtained um, cos it's not just yeah, like rote learnt knowledge*

444 Practicing the procedure in different contexts and with different target audiences was seen as a beneficial, helping
445 cement concepts, according to this quote from a focus group participant:

446 *“Um, maybe just adding to, I think having the multiple different tasks, like with concepts,*
447 *so you constantly had to think about the science side and the like, bicultural perspective*
448 *but in different formats a Facebook post which is, you know super, .. and then you had*
449 *one where it was like an email where you sort of had to be like, okay this is a different*
450 *format but the same thing and then talking to little kids, you're not going to use the same*
451 *words, same terminology, the same approaches to all of those things.”*

452 **5.4 Communication skills**

453 In 2022 students typically mentioned communication skills which was coded as either general communication
454 skills or part of bicultural competence in the case of specific bicultural communication.

455 *“The biggest thing I learnt in this course way how to communicate scientific ideas to a*
456 *non-scientific community in a way that helps them understand the ideas without creating*
457 *distress or make them feel that their culture is not heard and appreciated. This is a skill*
458 *that I will use within my future career when dealing with any people, both coworkers and*
459 *people within the public.”*

460 *“This idea of respectful communication is something that would be important wherever I*
461 *go, and is something that I hope to be able to practice in the future.”*

462

463 These are typical examples of student responses in 2022. The student mentions that they learnt how to
464 communicate (Science communication). They also mention culture (Bicultural skills). They do not mention any
465 content knowledge, however they do acknowledge that the communication and cultural skills they gained will be
466 important in their future career. Some students did not link their skills learnt to their future career but did mention
467 content knowledge and the importance of bicultural communication.

468 *“I learned a lot about Nz and Iceland volcanoes and how they compare to each other. I*
469 *also learned about some mitigation strategies and how to categorise different types of*
470 *volcanic eruptions. I also learned a new way of learning online through these videos and*
471 *answering the questions as I go through. I learned about incorporating Maori knowledge*
472 *and the importance of Maori involvement with geothermal projects.”*

473 Student’s reflections at the end of module also mentioned the same sentiment. In the next three quotes, students
474 discuss the value of an exercise where students were asked to comment on the following fictional social media
475 post: **“I have heard volcanoes erupt after earthquakes and I know Lyttleton volcano has had an explosive**
476 **history, I also read in the news that there are some hot springs that have got hotter since the earthquake, I**
477 **am not sure if I could cope with lava on top of everything- does anyone know if the volcano will erupt.**
478 **Posted by John B[”].**

479 ÷

480 *“I thought this was a very relevant module that taught me skills that I will definitely use. I*
481 *quite often see misinformation or posts similar to John’s, and I usually avoid them because*
482 *I don’t know how to approach them. This module gave me the skills to do so.”*

483 *“I found this module rather enjoyable, a lot of the time social media can provide a lot*
484 *misleading information that can generate unwanted fear in people or provide incorrect*
485 *information to people that can then be passed on. To be able to politely critique a member*
486 *of the general public and guide them towards more reliable scientific information.”*

487 *“I enjoyed this module as I have seen posts on social media that were not well*
488 *communicated, so learning better ways to communicate was nice to see.”*

489 These reflections show that the students felt the exercises were authentic and relevant to their learning journey.

490 **5.5 Bicultural Competence and Confidence**

491 The reflection question *“Has this course influenced your bicultural competence?”* (Fig. 35) showed that in 2021,
492 only 43% of students thought their confidence was influenced, in 2022 this number increased to 93%. When the
493 student answers were coded to explore their answers, it was apparent bicultural competence in 2021 was
494 interpreted as also knowing Icelandic experience with volcanoes by many students (Fig. 46), which isn’t a surprise
495 given that most of the virtual fieldtrip in 2021 was set in Iceland and featured Icelandic locals and narratives. This
496 is illustrated by the quote from a student reflection response:

497 *“I think the Iceland trip perhaps enhanced my bicultural knowledge on how other*
498 *communities deal with volcanic hazards.”*

499

500 A typical student response from 2022 was:

501 *“This course has definitely influenced my bicultural competence. I have gained a better*
502 *understanding of Maori and Icelandic cultures and the importance of being culturally*
503 *sensitive when communicating information.”*

504 *“Absolutely, this is the course that has gone most into it. In a lot of other courses I feel as*
505 *though it is only really mentioned at the start maybe fore a mihi and then is forgotten*
506 *about has the course goes on, but here it was brough through out the whole course which*
507 *was cool. It also was directly linked to what we were learning about like with the*
508 *geothermal resource email to the Maori land owner, rather than randomly being brought*
509 *in every now and then unrelated to what was goin on...I also like that there were Maori*
510 *~~expects~~experts in their fields who were directly teaching some of the concepts, that was*
511 *great.”*

512

513 The focus group transcriptions and discussion board responses also revealed the value that the course contributed
514 to the student’s bicultural confidence (Table 45). One example from a focus group discussion:

515 *“Yeah, I think the communication side of it was probably the most beneficial that I got out*
516 *of the course, um, especially yeah I suppose interacting with like manu whenua Māori and*
517 *um, and even just how to, I suppose adapt your communication to particular audiences”*

518

519 *“I feel like this part of the course has been very inclusive of what is the indigenous*
520 *approach to this, what is the cultural understanding, how can we incorporate the sort of*
521 *more indigenous aspects into how we approach science sort of like with the braided rivers*
522 *approach.”*

523 In this quote, the student shows a new appreciation for adapting their messaging to different cultures.

524 The following quotes from focus groups interviews in 2022 show that students value bicultural confidence and
525 competence skills:

526 *“...especially in New Zealand, it’s so important to incorporate that indigenous knowledge*
527 *when it comes to how we approach science”*

528

529 *“I feel like this part of the course has been very inclusive of what is the indigenous*
530 *approach to this, what is the cultural understanding, how can we incorporate the sort of*
531 *more indigenous aspects into how we approach science sort of like with the braided rivers*
532 *approach...”*

533

534 *I think it is a good reminder that a bicultural approach is necessary, especially within the*
535 *work place. I really liked how Ben used the karakea, as I felt it tied the course up nicely,*
536 *beginning to end.*

537

538 Students were very interested in the actual content and expressed that they would like to get a deeper
539 understanding of the subject, for example these discussion board quotes:

540 *I found the Māori volcanology legends fascinating and I would love to learn more about*
541 *how they view volcanoes and how we can use a mixture of both Western and Māori*
542 *knowledge to inform hazards and risks.*

543

544 *Learning about the volcano family, particularly in the context of Maori mythology is an*
545 *interesting idea that we often don't get to experience as science majors. Very cool!*

546

547 *I also enjoyed the input from Dan, on the ways we can implement maori/ native cultural*
548 *information, as you currently don't see a large amount of scientific literature with*
549 *consideration of these kind of inputs.*

550

551 **6 Limitations**

552 The research and the course assessment were intertwined, for example the instructor was also one of the
553 researchers, and part of the assessment (the reflections and discussion boards) were used as research artifacts.
554 However, marks for reflections and discussion boards were only for completion, and the student answers were
555 anonymized before the instructor saw them (e.g. Watson, 2022) as per ethics agreement. Similarly, when the
556 research was presented to the students and their participation in the research was requested, the instructor was out
557 of the room as per ethics agreement. However, considering that the research relies on the students' perception of
558 their learning, it is possible that students' perception of what they were learning was influenced by the research.
559 Given that this study is a comparison between two years, and both years the research methodology was identical,
560 comparisons between both cohorts should be uninfluenced by the research.

561 **7 Discussion**

562 By comparing the results from the two separate classes, we can get some insight into the effect of the course
563 changes. The analysis shows that students in the post-intervention group were more likely to mention skills in
564 their reflections on what they learnt (Fig. 43). When analysed further, the skills that were mentioned were most
565 likely to be relating to communication, online environment, and bicultural competence. This increase in
566 mentioning skills aligns with the instructors' goals for the changes implemented in the course, which were
567 specifically to improve the communication skills and bicultural confidence of the students, (Fig. 24).

568 Overall, the student reflections show that the change from a lecture-based classroom setting to a flipped classroom
569 with an interactive, engaging, and pedagogically grounded online environment was an effective classroom
570 intervention. The 2022 iteration contained more interactive elements and functionality aligned to communication
571 and bicultural competence. It provided more authentic assessment and opportunities for deliberate practice (e.g.
572 Benjamin & Tullis, 2010), ~~in a universal design for learning framework (e.g. Van Gog et al., 2005)-which are~~
573 ~~pedagogical approaches that are linked to improved learning. The delivery of both 2021 and 2022 content was~~
574 ~~during the COVID pandemic although neither were affected directly by lockdowns, the reflection questions~~
575 ~~analysed here did not address the impact of COVID pandemic on learning, although this context is important to~~
576 ~~consider as has been shown to influence students and instructors' opinions of online learning (Chakraborty et al.~~
577 ~~2021).~~

578 The intervention contained additional exercises to encourage students to engage with class material outside of the
579 classroom and apply what they learned to real world situations that they expect to experience in a future career.
580 These exercises can be defined as authentic assessments (Kaider et al. 2024). Students linked these authentic
581 assessments with their perceived learning in the discussion boards, reflective posts, or focus groups where students
582 reflected on specific exercises linking these exercises to learning specific career useful skills. Students quotes
583 showed that they felt that the course provided them with opportunities to practice skills to communicate
584 effectively. They felt that these authentic assessment exercises could help them develop skills that could be useful
585 in future careers. Some quotes reveal that these skills were something that the students had already encountered
586 in their personal lives and therefore valued as authentic. These skills are not only related to the courses' learning
587 goals, and also can be linked to UC's BSc graduate attributes of "Biculturally competent and confident" and
588 "Employable" specifically around "Communication". Although not directly related to a specific geology career,
589 they are, in essence, skills required to become an informed BSc graduate and citizen.

590 A clear change between both cohorts is the bicultural confidence context that students mentioned in their
591 reflections. In the 2021 cohort, most of the group discussed Icelandic culture when asked about bicultural
592 confidence and competence, however almost all students took it to mean Māori culture in the 2022. Although this
593 in not the case overseas (e.g Clark 2006), in New Zealand, biculturalism specifically refers to the existence of
594 two distinct cultures, Māori culture and New Zealand culture, based primarily on values from British settlers
595 (Eketone, & Walker, 2015). ~~The course teachers meant this~~ This latter definition ~~of biculturalism is relevant here~~
596 ~~and when they asked about interpreting students' responses regarding~~ bicultural confidence and competence in the
597 reflective questionnaire in both years. That students mentioned Māori culture less in 2021 is likely related to the
598 lack of Māori experts and assessments relating to bicultural confidence featured the 2021 version of the course,
599 and therefore the students might have felt that bicultural confidence in the context of the course did not specifically
600 relate to Māori culture. The 2022 data shows that bicultural understanding was at least partially shifted and was
601 related to the Māori experts featured in the course and the related assessments. Improved cultural competency has
602 been reported to enhances people's well-being by bringing together indigenous and nonindigenous knowledge and
603 practices (Eketone & Walker, 2015)).

604 Students quotes overall showed a genuine appreciation for the Mātauranga Māori and bicultural content.
605 Reflections showed that the content in the 2022 version of the course felt authentic and better integrated in the
606 course compared to other courses. Students appreciated that the instructor lead by example by adhering to Māori
607 tikanga (~~customs~~) while delivering the course (~~customary practices~~) while delivering the course. Our model of

608 MOOC, flipped classroom and focus on developing lecturer-student and peer relationships is an expression of
609 Māori tikanga, and enabled students to experience it through undertaking the course. For example, students
610 experienced whanaungatanga (meaning “creating cohort connection through relationship building” in this context)
611 through the intentional relationship building, and further by writing and sharing their pepeha, reading other
612 students’ pepeha, an activity that the students highlighted in their reflections. Students also commented that they
613 appreciated videos shared by our cultural experts, where cultural values were frequently expressed such as
614 kaitiakitanga (intergenerational sustainable guardianship of the land) around the geothermal industry.

615 **8 Conclusions**

616 Our research describes the pedagogy behind our course and the critical roles that all the members of the team had
617 in course development ~~data relies.~~ We then present and discuss data on students’ perceptions of their learning
618 and how this relates to elements of the course.

619 Learning advisors guided us to produce engaging interactive activities on the edX online platform, these were
620 critical in allowing creation of activities that enabled deliberate practice of skills in a variety of assessment types.
621 Similarly, our cultural advisors who also delivered authentic content, providing essential mana and expertise in
622 cultural knowledge and how to design assessments that reflect and test this knowledge. These roles were essential
623 to achieve the learning associated with skills-based learning objectives in 2022, and this was in addition to the
624 critical roles of the instructor and 3D ~~Visualisation~~visualisation tools developer as discussed in Watson et al.
625 (2022;2023)

626 Students in 2022 were more likely to mention communication skills, bicultural skills, or ~~skill~~skills relating to
627 flexible learning when asked to reflect on their learning. Several students in 2022 specifically mentioned the newly
628 introduced authentic assessments and linking this to their skill learning. Some students also mentioned the
629 opportunity to practice skills in a variety of contexts and tools.

630 The team-based development of the flexible course, with multiple experts and repurposing of videos should
631 provide a template for the development of other courses with skills-based course learning goals. In addition, the
632 research supports the use of multiple flexible modes of authentic assessment to promote skills-based learning.

633 In summary, students’ reflections showed that during the course they gained bicultural confidence and
634 communication skills. Our consideration of Māori tikanga, Mātauranga (knowledge) and values such as
635 kaitiakitanga (guardianship) and whanaungatanga (relationships) alongside scientific methods fostered the ability
636 to communicate science with a range of people with different academic and cultural backgrounds, which is
637 important in most careers in Aotearoa NZ and globally. We encourage other academics to uphold local indigenous
638 cultural perspectives when developing and delivering science courses.

639 **Foot notes**

640 ¹Although Aotearoa is a Māori name for New Zealand’s North Island, to reflect the nations bicultural foundation
641 it is commonly and increasingly used in this way, e.g., Aotearoa New Zealand, or simply Aotearoa NZ, to mean
642 New Zealand.

643 **Author contribution:**

644 BK and JD designed the experiments and JD and KE carried them out. All Authors contributed to the design and
645 re-development of the course. BK prepared the manuscript with contributions from all co-authors.

646 **Competing interests:**

647 The authors declare that they have no conflict of interest.

648 **Ethical statement**

649 The study was reviewed and approved by the University of Canterbury's human research ethics committee (Ref:
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Course run	Implementation and assessment	Research data
2021	10hrs lectures with assessed in class exercises 15hrs laboratory work assessed workbook 4hrs online VTF and assessed online discussion boards <u>2 hrs Workshop in last 2 weeks of course:</u> Study for exam and 2.5 hr final exam	End of course reflection Focus groups
2022	12hrs online MOOC VTF online exercises <u>15hrs laboratory work and assessed workbook</u> 5hrs flipped workshops and assessed workbook 15hrs laboratory work and assessed workbook : Science communication project	End of course reflection Weekly reflections Focus groups

854 **Table 1: Course structure and research data from both runs of the course**

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<u>2021</u>	<u>Informal discussion with group (10 min)</u> <u>Handout with applied interpretative sketches and reflections. (35 min)</u>
<u>2022</u>	<u>Highlighting exemplar online responses from students(5min)</u> <u>Reflection on confidence of achieving learning goals as guidance for workshop (5min)</u> <u>Warm up question as mental ramp up(5min)</u> <u>Mini interactive lecture based on content with low confidence (10min)</u> <u>Two group workbook questions, designed to explore content and develop communication skills (20min)</u>

856 **Table 2: Workshop structure comparison from both runs of the course**

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Online content	Video	Multichoice	Discussion boards	Interactive	End of module
VFT (2021, last two weeks)	Instructor, and Iceland experts	Content focussed	Prior knowledge, Reflection, Sketching skills	3D rocks, 360 video, 3D landscapes	Applied question (+one module with reflection)
MOOC (2022, every week)	Instructor, Indigenous leaders and scientists	Content and skill focussed	Prior knowledge Reflection Sketching skills	3D rocks, 360 video, 3D landscapes Mapping with	Reflection after specific goals achievement exercise.

	Iceland and NZ experts		Communication skills	communication and cultural elements	
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859 **Table 23: Details of online content.**

Reflection Questions	Question aspects	Coding categories	Results	
			2021 (Total n = 21)	2022 (Total n = 27)
Q1. What did you learn in this course and why is it important to you and/or your potential career?	What was learnt?	Content knowledge (Factoids)	21	23
		Skills, 2021	18	26
		Attitudes	11	4
	Is what you learnt important to your future study/career/personally?	Yes	17	21
		No	1	0
		Not Stated	3	4
Q2. Has this course influenced your bicultural competence (BCC)?	Did the course improve your BCC?	Yes	9	25
		No	8	1
		Unsure	3	1
		Not stated	1	0
	What kind of cultural knowledge was improved?	Māori	5	17
		Icelandic	8	1
		Other	1	7
		Not stated	12	2

860 **Table 34. Coding methodology. The numbers reported in the columns are the number of students that mentioned the**
861 **category in their reflections. n is the total number of answer.**

Focus Group Questions	Reflective Questionnaire Equivalent
How has the course affected/influenced/helped/assisted your learning in volcanology/geology?	Q1. What was learnt? (Facts/Attitudes)
How has the course affected the way you feel/think about your science communication skills?	Q1. What was learnt? (Skills)
How might your experience with the course help you in the future?	Q1. Is what you learnt important to your future study/career/personally?

<p>How has the course affected the way you feel/think about your bicultural competence and confidence?</p>	<p>Q2. Has this course influenced your bicultural competence (BCC)?</p>
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862 **Table 45.** Focus group questions mapped onto the reflective questionnaire questions

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Figure 1. An example of two pages of a student communication project aimed at educating children about hazards from gases in the city of Goma in the Democratic Republic of Congo.

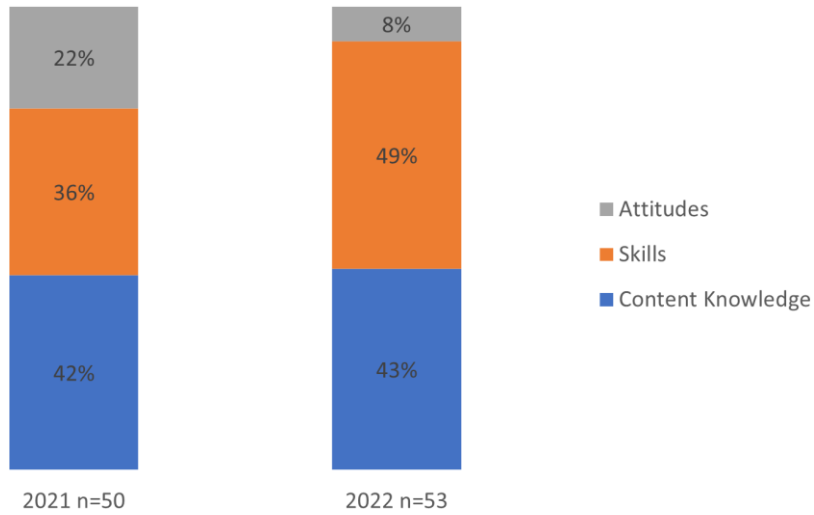
Goals reflection

	Very confident	Fairly confident	Not so confident
Locate Krafla in the context of the volcanism and tectonism of Iceland.	65%	31%	4%
Record systematic and detailed observations of an outcrop and a rock of a typical obsidian subglacial eruption.	46%	46%	8%
Record and compare systematic and detailed observations of the map-scale geology and geomorphology of tuff cones, lava domes and/or caldera volcanoes.	42%	54%	4%
Use rocks to communicate your understanding of volcanic processes and products to a diverse group of primary school	50%	38%	12%

- I personally had real trouble looking at the outcrops as I feel like the quality wasn't ideal. I knew it was a dyke and it's structure, but it was difficult to make all the observations correctly even when I was looking really hard and trying my best. I really enjoyed the hazard exercise, as explaining the rocks to children really cemented that I knew the difference and could explain it in a simple way. I also didn't know there was such a thing called a rootless volcano, so that was super interesting to learn! I enjoyed having the exercise to identify them too as it made it a bit clearer what they looked like.

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Figure 2. Example slide from the start of a workshop session in 2022, showing learning goals, a summary of student self-reported confidence on learning goals for the module, and one example justification from students. This slide shows how learning goals are constructively aligned by giving students the opportunity to self-report and reflect on their achievement of the goals.



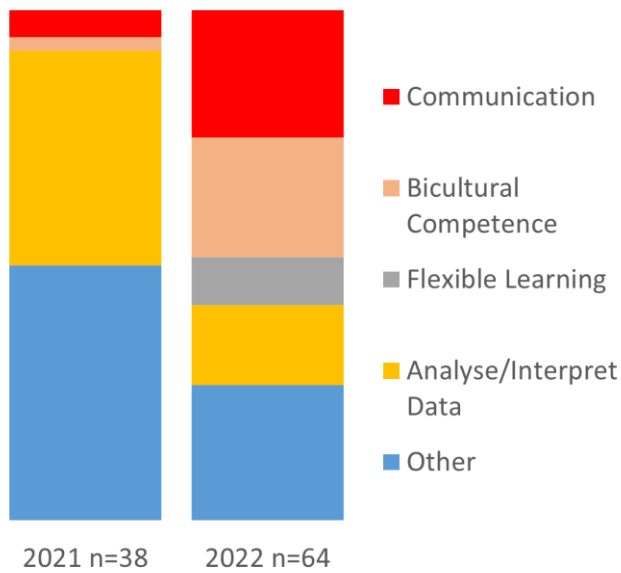
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Figure 13. Relative coding results from reflection data. n is total number of the code category mentions (one answer might have multiple mentions) .



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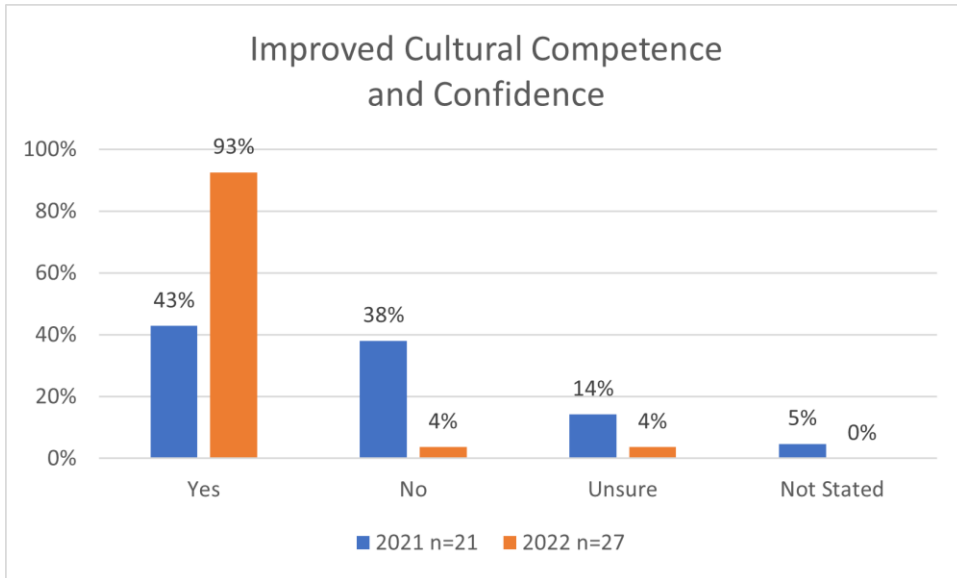
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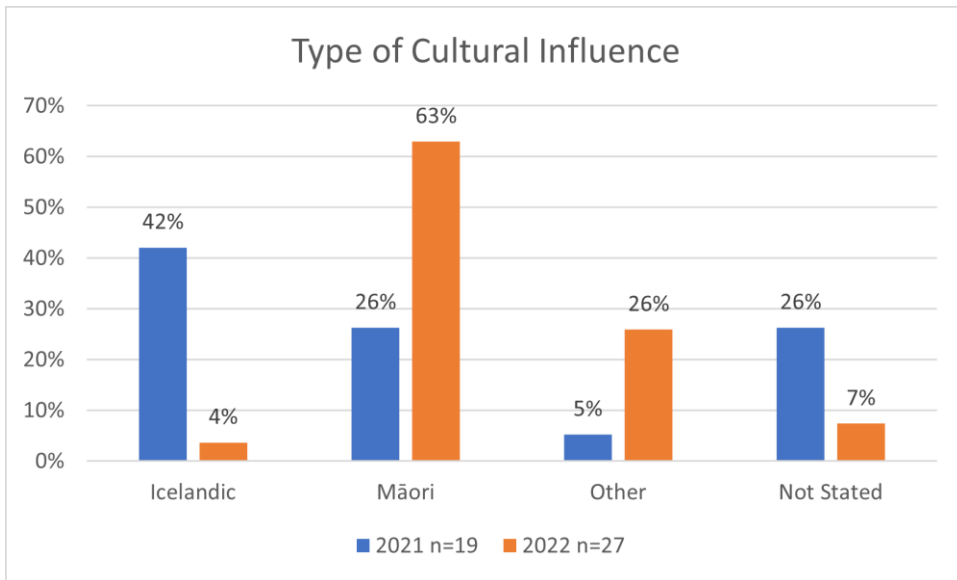
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Figure 24. 2021 and 2022 data comparison of skills mentioned by students in their reflections. (one answer might have multiple mentions).



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887 **Figure 3.5.** Summary of cultural competence perception in student reflection questions



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889 **Figure 4.6.** Summary of cultural influence type mentioned in student reflection questions.