Co-Designing Climate Science Curricula with Indigenous Communities: A Participatory Framework

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Abstract.

Building on our framework for integrating Indigenous Knowledge Systems into climate science curricula, this paper reports a participatory co-design process with Māori and Bhutanese communities. Climate science curricula in secondary schools have typically been developed by disciplinary experts and delivered through assessment regimes that privilege empirical measurement, leaving little space for the relational, place-based knowledge that Indigenous communities hold about changing environments. This study asked whether a participatory framework could produce a curriculum and, critically, an assessment approach that both communities and science educators would recognise as legitimate. Over fourteen months, co-design workshops were conducted with two iwi-affiliated communities in Aotearoa New Zealand and two village communities in eastern Bhutan, involving 58 community participants, 21 teachers and 6 climate scientists. Data comprised workshop records, artefacts, 34 follow-up interviews and pilot implementation in six classrooms. Thematic analysis identified four design principles that emerged in both settings: reciprocity in knowledge exchange, place as the organising unit of inquiry, intergenerational authority and the co-existence of explanatory frames. Outcomes include a shared assessment rubric that values both empirical and relational knowledge, structured around six criteria that assess observational rigour alongside relational understanding, community accountability and ethical conduct. Pilot use indicated that teachers could apply the rubric consistently and that students engaged with both knowledge forms. The paper proposes a participatory framework of five stages and discusses its transferability, its tensions and the conditions under which co-designed assessment can be sustained within national qualification systems.

Keywords: Indigenous knowledge, climate science education, participatory co-design, assessment rubric, Māori and Bhutanese communities

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1. Introduction

Climate change education has expanded rapidly in secondary curricula across the Asia-Pacific region, driven by national commitments (UNESCO, 2021), student activism and the visible effects of a warming climate on communities. Most curricula treat climate science as a body of empirical knowledge derived from measurement and modelling, and most assessment regimes reward students for reproducing that knowledge. Indigenous communities, however, hold extensive knowledge of environmental change grounded in long-term observation, seasonal calendars, place-based relationships and ethical obligations to land and water. The question of how such knowledge should relate to school science has been debated for decades, but the debate has largely concerned curriculum content rather than assessment, and it has rarely been conducted with communities as co-designers rather than consultees.

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In our earlier study (Rangi & O'Connor, 2025) we proposed a framework for integrating Indigenous Knowledge Systems into modern climate science curricula, drawing on case material from Aotearoa New Zealand. That framework identified principles for content integration and warned that assessment was the point at which integration most often failed, because rubrics designed for empirical knowledge could not recognise relational knowledge and thereby signalled to students that it did not count. The present paper takes up that warning. It reports a participatory co-design process, conducted with Māori communities in Aotearoa and Bhutanese communities in the eastern districts of the kingdom, whose aim was to produce curriculum materials and a shared assessment rubric that would value both empirical and relational knowledge.

The choice of two national settings was deliberate. Aotearoa has a formal framework for Māori knowledge in education and an established discourse of partnership under Te Tiriti o Waitangi, whereas Bhutan has a national development philosophy that foregrounds cultural preservation and environmental stewardship but little formal apparatus for community participation in curriculum. Comparing the two allowed the study to ask which features of the co-design process were shaped by institutional context and which emerged from the encounter between community knowledge and school science regardless of context. The addition of a Bhutanese co-author, whose institution has responsibility for teacher education in the country, was central to this extension.

The paper addresses three questions. What design principles emerge when communities, teachers and scientists co-design climate science curriculum? What form does an assessment rubric take when it is required to value both empirical and relational knowledge? Under what conditions can such a rubric be applied consistently and sustained within national assessment systems? The paper reviews relevant literature, describes the participatory methodology, presents the design principles, rubric and pilot findings, discusses transferability and tensions and concludes with limitations and future directions.

2. Literature Review

2.1 Indigenous knowledge and science education

Scholarship on Indigenous knowledge in science education has moved from early debates about whether such knowledge counts as science toward frameworks for coexistence. Aikenhead and Ogawa (2007) distinguish Indigenous, neo-Indigenous and Euro-American ways of knowing nature and argue that each has integrity on its own terms. Bartlett et al. (2012) describe two-eyed seeing, a Mi'kmaw concept in which learners draw on the strengths of Indigenous and Western knowledge together, and this framing has been widely adopted in environmental education. In Aotearoa, Smith (2012) established the foundations of Kaupapa Māori research, in which Māori control the purposes and processes of inquiry, and McKinley and Smith (2019) review the incorporation of mātauranga Māori into science curricula and note persistent tensions around assessment. Climate change specifically has been a focus of Indigenous knowledge scholarship because communities have observed change directly; Whyte (2017) argues that Indigenous climate knowledge is inseparable from relationships of responsibility to land and non-human kin, so that extracting observations from that relational context misrepresents the knowledge. At the level of global environmental assessment, Hill et al. (2020) describe procedures for weaving Indigenous, local and scientific knowledge without subordinating one to another, and their emphasis on mutual validation informed the assessment criteria developed here.

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2.2 Participatory and co-design approaches

Participatory design has roots in Scandinavian workplace democracy and has been extended to education through co-design of curriculum and learning environments (Penuel et al., 2007). Its core commitment is that those affected by a design should shape it, and its typical practices include iterative workshops, prototyping and shared decision-making. In Indigenous contexts, participatory approaches intersect with decolonising methodologies (Smith, 2012), which add requirements of community ownership of knowledge, reciprocity and benefit to the community. Cochran et al. (2008) discuss the ethics of research with Indigenous communities and emphasise that participation is meaningful only when communities can shape questions and interpret findings. The present study draws on both traditions and treats co-design as a process governed by community protocols rather than by researcher timelines.

2.3 Assessment and the recognition of knowledge

Assessment shapes what is taught and what students take seriously. Where assessment rewards only empirical reproduction, integrated curricula are undermined regardless of their content. Rubric-based assessment has been proposed as a means of making criteria explicit and of accommodating diverse forms of performance (Brookhart, 2013), but rubrics embody values, and rubrics designed within a single epistemology will privilege that epistemology. Our earlier work (Rangi & O'Connor, 2025) identified the absence of assessment criteria for relational knowledge as the main structural barrier to integration in Aotearoa, and the Bhutanese curriculum reform literature notes a similar gap between the philosophy of Gross National Happiness and examination-driven practice (Schuelka & Maxwell, 2016). Thematic approaches to analysing participatory processes (Braun & Clarke, 2006) are well suited to identifying the design principles through which such gaps might be closed.

3. Methodology

3.1 Research design and settings

The study was designed as a participatory co-design process with embedded qualitative research, conducted over fourteen months from February 2025 to April 2026. Four communities participated: two iwi-affiliated communities in the Bay of Plenty and Northland regions of Aotearoa, and two village communities in the Trashigang and Mongar districts of eastern Bhutan. Communities were approached through existing relationships held by the authors and their institutions, and each community determined its own terms of participation, including who would participate, where workshops would be held and how knowledge would be recorded. In Aotearoa the process was governed by a kaitiaki group of elders; in Bhutan it was governed by village elders and the local gewog administration in consultation with the district education office. Ethical approval was obtained from the University of Auckland and the Royal University of Bhutan, and agreements on knowledge ownership were negotiated with each community before workshops began. Table 1 summarises the participants.

Table 1: Participants in the co-design process by setting and role

Role	Aotearoa (n)	Bhutan (n)	Total (n)
Community elders and knowledge holders	14	12	26
Other community members (including youth)	18	14	32
Secondary teachers	11	10	21
Climate scientists	3	3	6
Total participants	46	39	85

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Workshops held	9	8	17
Pilot classrooms	3	3	6

Source: Authors' project records (2026)

3.2 Co-design process

The co-design process unfolded in five stages that were planned iteratively with the communities and that form the basis of the framework proposed in Section 5. In the relationship stage, researchers spent time in each community without a design agenda, participating in seasonal activities and listening. In the mapping stage, community members and scientists jointly documented local observations of environmental change alongside instrumental records, producing place-based climate narratives. In the design stage, teachers, community members and scientists developed learning sequences around those narratives. In the assessment stage, the same participants developed and refined criteria for assessing student work. In the pilot stage, teachers implemented the sequences in six classrooms and the rubric was applied and revised. Seventeen workshops were held in total, each lasting between half a day and two days, with interpretation between te reo Māori, English, Dzongkha and Sharchopkha as needed.

3.3 Data and analysis

Data comprised workshop records including audio where permitted, photographs of artefacts such as seasonal calendars and rubric drafts, 34 follow-up interviews with community members, teachers and scientists, and pilot data including 112 assessed student work samples and teacher rating records. Analysis followed reflexive thematic analysis (Braun & Clarke, 2006), with an initial coding by the three authors and validation of themes by community representatives, consistent with the principle that communities interpret as well as generate knowledge (Cochran et al., 2008). Rubric consistency in the pilot was examined by having pairs of teachers rate common samples and computing agreement. All community knowledge reported in this paper is presented at a level of generality agreed with the communities; specific observations and narratives remain community property.

4. Results

4.1 Emergent design principles

Four design principles emerged in both settings, although their expression differed. Reciprocity in knowledge exchange required that scientists share instrumental data and explanations with communities in accessible forms, and that community knowledge be used only in ways the community sanctioned; in Aotearoa this was framed through the concept of utu, and in Bhutan through obligations of hospitality and merit. Place as the organising unit of inquiry meant that learning sequences were built around a specific river, coastline, forest or valley rather than around abstract climate concepts, with global processes introduced as explanations of local change. Intergenerational authority meant that elders were recognised as authoritative sources whose knowledge students were expected to seek, record and honour, which in Bhutan required negotiation with school norms that positioned teachers as sole authorities. The co-existence of explanatory frames meant that students were not asked to reconcile Indigenous and scientific accounts into a single explanation but to hold both, understand what each could and could not say, and reflect on their relationship.

Table 2 shows the frequency with which each principle was invoked across workshop records and interviews in the two settings. The high frequency of the co-existence theme in Bhutan reflected extended discussion among teachers about how it could be squared with

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examination expectations, while the higher frequency of reciprocity in Aotearoa reflected the salience of data sovereignty in that context. These differences illustrate how institutional context shapes the emphasis but not the content of the principles.

Table 2: Frequency of design principle themes in workshop records and interviews

Design principle	Aotearoa coded segments	Bhutan coded segments	Total	Share (%)
Reciprocity in knowledge exchange	94	51	145	24.8
Place as organising unit of inquiry	71	68	139	23.8
Intergenerational authority	58	63	121	20.7
Co-existence of explanatory frames	62	88	150	25.6
Other themes	17	13	30	5.1
Total	302	283	585	100.0

Source: Authors' thematic analysis (2026)

4.2 The shared assessment rubric

The central product of the process is an assessment rubric with six criteria, each described at four performance levels. Table 3 presents the criteria and their sources. Three criteria concern what would conventionally be regarded as empirical knowledge: observational rigour, the quality and care with which students record environmental observations; explanatory reasoning, the ability to connect local observations to climate processes; and use of evidence, the ability to draw on instrumental and community records. Three criteria concern relational knowledge: relational understanding, the ability to articulate relationships between people, place and non-human beings and how change affects them; community accountability, the extent to which students have sought, acknowledged and returned knowledge to community sources; and ethical conduct, adherence to community protocols in gathering and presenting knowledge. The rubric deliberately places the two sets of criteria at equal weight, and performance descriptors were written jointly by elders, teachers and scientists.

Table 3: Criteria of the shared assessment rubric and pilot rating agreement

Criterion	Knowledge domain	Principal authors of descriptors	Weight (%)	Rater agreement (κ)
Observational rigour	Empirical	Scientists and teachers	16.7	0.78
Explanatory reasoning	Empirical	Scientists and teachers	16.7	0.74
Use of evidence	Empirical	Scientists, teachers and elders	16.7	0.71
Relational understanding	Relational	Elders and teachers	16.7	0.72
Community accountability	Relational	Elders	16.7	0.81
Ethical conduct	Relational	Elders	16.7	0.83

Source: Authors' project records and pilot rating data (2026)

4.3 Pilot implementation

The rubric was applied to 112 student work samples across the six pilot classrooms, with each sample rated independently by two teachers. Agreement, expressed as Cohen's kappa,

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ranged from 0.71 to 0.83 across criteria, indicating substantial consistency. Agreement was highest for community accountability and ethical conduct, which surprised the teachers, who had expected relational criteria to be the most subjective; in interviews they attributed this to the concreteness of the descriptors elders had written, which specified observable actions such as seeking permission and returning findings. Agreement was lowest for use of evidence, where teachers differed on how to weigh community records against instrumental data. Student work showed engagement with both knowledge forms: 87 of the 112 samples included both a community narrative and instrumental data, and 64 included explicit reflection on the relationship between them. Teachers reported that students who had previously been disengaged from science, in several cases students from the participating communities, produced some of the strongest work on the relational criteria and that this had visibly altered their standing in the classroom.

5. Discussion

The findings address the warning issued in our earlier framework (Rangi & O'Connor, 2025) that assessment is where integration fails. The shared rubric demonstrates that criteria for relational knowledge can be articulated with sufficient precision to be applied consistently, and the pilot agreement data indicate that such criteria are not inherently more subjective than empirical ones. This challenges an assumption embedded in much assessment practice and in the literature on rubric design (Brookhart, 2013), namely that only empirically demonstrable performance can be assessed reliably. The finding that elder-authored descriptors produced the highest agreement suggests that reliability depends on who writes the criteria and how concretely, rather than on the domain of knowledge being assessed.

The four design principles resonate with existing scholarship while adding specificity. Co-existence of explanatory frames is a practical expression of two-eyed seeing (Bartlett et al., 2012) and of the coexistence that Aikenhead and Ogawa (2007) advocate, and the emphasis on relational understanding reflects Whyte's (2017) argument that Indigenous climate knowledge cannot be separated from responsibility. What the co-design process adds is a demonstration of how these commitments translate into curriculum and assessment decisions, and evidence that the same principles emerged in two settings with very different institutional apparatus. This suggests that the principles derive from the encounter between community knowledge and school science rather than from any particular policy framework, which supports their transferability while cautioning that their expression will vary.

The participatory framework that emerges from the process comprises five stages: relationship, mapping, design, assessment and pilot. Two features distinguish it from conventional curriculum development. The relationship stage precedes any design activity and is governed by community rather than researcher timelines, consistent with decolonising methodology (Smith, 2012) and with the ethics articulated by Cochran et al. (2008). The assessment stage is treated as a design activity in its own right, involving the same participants as curriculum design, rather than as a technical task left to educators. In both settings, participants identified the assessment stage as the point at which the process became consequential, because it determined whether community knowledge would count in the qualifications students carried out of school.

Tensions were present and should not be understated. In Bhutan, teachers were concerned that time spent on community inquiry would disadvantage students in national examinations, a concern consistent with the gap between educational philosophy and examination practice noted by Schuelka and Maxwell (2016), and the district education office agreed to the pilot only on the understanding that examination preparation would not be reduced. In Aotearoa,

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the kaitiaki group raised concerns about the circulation of community knowledge in student work that might be shared beyond the school, and the ethical conduct criterion was strengthened in response. In both settings, scientists initially questioned whether relational criteria belonged in a science assessment, and their shift over the course of the process, which several described in interviews as a change in their understanding of what climate knowledge is, was itself an outcome of co-design. Sustaining the rubric within national systems will require recognition by qualification authorities, which is the subject of ongoing engagement in Aotearoa through the standards for mātauranga-informed science described by McKinley and Smith (2019), and which in Bhutan would require curriculum board approval. Participatory approaches in education (Penuel et al., 2007) have often produced local innovations that fail to scale for exactly this reason, and the study offers no guarantee of a different outcome.

6. Conclusion

This paper reported a participatory co-design process with Māori and Bhutanese communities that produced climate science learning sequences and a shared assessment rubric valuing both empirical and relational knowledge. Four design principles emerged in both settings, a six-criterion rubric was developed with elders, teachers and scientists as co-authors, and pilot implementation showed that teachers could apply the rubric consistently and that students engaged with both knowledge forms. The study extends our earlier framework by demonstrating that the assessment barrier to integration can be addressed through co-design, and it proposes a five-stage participatory framework whose distinctive features are a relationship stage governed by community protocols and the treatment of assessment as a co-design activity.

The study is limited by its scale, involving four communities and six pilot classrooms, and by the absence of student outcome measures beyond assessed work. The pilot was conducted with teachers who had participated in co-design and may not generalise to teachers encountering the rubric without that experience. Future work should examine the rubric's use by non-participating teachers, follow students to assess longer-term effects on science identity and community relationships, and engage qualification authorities in both countries to test whether co-designed assessment can be recognised at the national level.

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