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NĀU I WHATU TE KĀKAHU, HE TĀNIKO TAKU

The Apiscope Buzz: A mixed methods action research project investigating STEM to STEAM using the Apiscope as a tool for differentiated teaching and learning

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Introduction

This Teaching and Learning Research Initiative (TLRI) project was a 2-year exploratory study focusing on differentiating the curriculum in response to individual learner differences. The project was designed to explore learning and teaching of differentiated scientific content through observational processes and the expression of that learning through the creative arts. This exploration was undertaken in two classrooms at Avalon Intermediate School and Newlands Intermediate School that were each provided with an observational beehive called an Apiscope. These observational beehives were central to the project, which explored how the study of bees can be used to facilitate the teaching of key concepts related to living systems—sustainability, work, survival, structures, patterns—that, in turn, promote interdisciplinary learning and establish an optimum situation for innovative differentiated teaching and learning.

In other words, we set out to explore how the study of a living system could provide a context for STEM (science, technology, engineering, and mathematics) content that is conceptual, complex, and sophisticated. We wondered how accessing rich content, through authentic, experiential observational processes, would encourage students to express their learning artistically, shifting from STEM to STEAM learning. And we were curious how creativity and artistic expression, through dance, drama, music–sound, creative writing, and the visual arts, might provide new modes for articulating learning. We were especially interested in understanding how innovative opportunities to express learning creatively (across a range of curriculum areas) might enable student choices, multi-modal methods of communication of learning, and collaborative student production of outcomes, responding to a range of different abilities.

Throughout the project and underpinning all aspects of the research, we sought to understand how differentiation, as a response to learner differences, was enacted by teachers. Differentiation is the tailoring of content, processes, and products to better match diversity and it begins to address inequities in education outcomes, especially for priority learners. Differentiated teaching recognises and responds to individual learners' differences in abilities, learning preferences, ages, cultures, genders, rates of learning, outcomes, motivations, and parental and whānau support. Differentiated teaching maximises all students' access to learning and opportunities for growth.

Research questions

Our research questions were:

1. How can teachers use an observational beehive to stimulate the design and implementation of differentiated teaching and learning based on:
 - STEM (Science, Technology, Engineering, and Mathematics) content?
 - observation-led processes of learning?
 - expressions of learning through the creative arts?
2. Does differentiated teaching and learning with the Apiscope develop and enhance students' knowledge, skills, and attitudes in relation to:
 - literacy and numeracy, when developed through STEAM (from STEM to STEAM means including the arts as a vital tool to expand modes of investigation for students and expressions of their learning)?
 - key competencies of using language, symbols and texts; managing self; relating to others; thinking; and participating and contributing?
3. What is the relationship between differentiated STEAM teaching and learning, and changes in the knowledge, skills, and attitudes of priority learners who may have special needs (including gifted and talented), identify as Māori or Pasifika, or come from low socioeconomic backgrounds?

Research methodology

Our project aimed to use a mixed methods action research framework (Ivankova, 2015), which we felt would enable a participatory, fluid, and creative design of an exploratory study. Our study, unlike many mixed methods action research studies in education, was not led solely by teacher practitioners; rather, the study involved teachers working with an artist researcher and an education researcher alongside other practising artists (including musicians, photographers, filmmakers, illustrators, and writers) and beekeepers. Also, we hoped that using mixed methods action research would enable professional learning, development, and support to influence changes in teaching practices, particularly related to the inclusion of the creative arts as a method to express learning across multiple disciplines.

Importantly, we chose mixed methods action research because of its potential to allow us to think differently about educational research and to use multiple ways of making sense of what was going on from different disciplinary perspectives (Ivankova, 2015). Mixed methods action research requires reflective practice and collaborative approaches as practice-led research teams seek to understand “what works” (Riley & Moltzen, 2011). Practice-led research is an approach that allows creative or teaching practices *into* research, and, in doing so, legitimises the knowledge those practices reveal and endorses the methodologies of practice (Ivankova et al., 2019).

Our incorporation of art methods and processes is an experimental contribution to mixed methods research, and an important aspect of this exploratory research project. Creative practice research sees practice and research working hand in hand: the knowledge acquired from creative practice may inform further critical exploration. The creative practice itself may lead to changes in practice, enable experimentation, and foster collaborative practice. In other words, within this participatory research context, art contributed more than student outcomes (i.e., the books, drawings, photographs, videos, songs, and designs); creative arts research methods were embedded within the iterative reflective cycles of the mixed methods action research. Art as a research method is termed “practice led” and is our means to position art centrally within the STEM to STEAM research and learning environment.

Mixed methods action research, which typically focuses on quantitative and qualitative data, also enabled the mixing of educational research and creative practice research for this exploratory education project—and this led us on a transdisciplinary research journey. Transdisciplinary investigations enable different disciplines to work together to create innovations that integrate and move beyond discipline-specific approaches. This is complex, powerful, and “messy” research that does not follow a tidy, neatly boxed methodological pattern but aims to build and create practices iteratively, open to new questions emerging throughout the process.

Research design

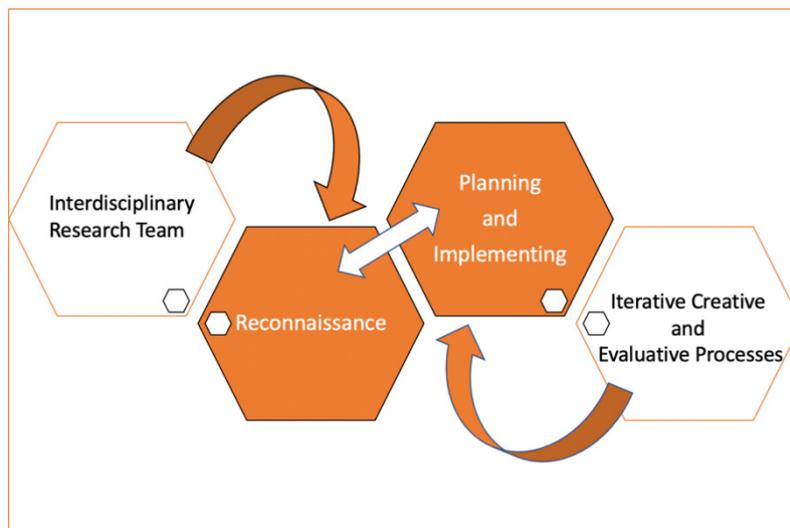
Within this project, we used Ivankova’s (2015) Mixed Methods Methodological Framework for Action Research as a framework to guide our exploratory work. This framework has six phases, as shown in Figure 1. As an action research project, the cycles allowed for fluidity and flexibility that became critical to this project which was centred on a living system—a colony of bees. This framework also facilitated explorations in authentic learning environments using creative processes. Importantly, this framework enabled informal methods that added to the richness and complexity of the artistic outcomes and provided the basis for further iterative cycles of the creative process, enabling ongoing opportunities for teachers and researchers to explore experimental approaches to differentiation together.

FIGURE 1. **The Mixed Methods Action Research Cycle (Ivankova, 2015)**



This project was focused on two classrooms in which students were interacting with teachers and artists as researchers—and with each other. The creative process was central to the research process and required interactive, inclusive, and iterative data collection and analysis, as shown in our adaptation of Ivankova’s framework (Figure 2). What this diagram shows is the influence and engagement of the interdisciplinary research team upon each cycle of reconnaissance, the interactivity between making sense of what was going on as we collaboratively planned and executed the creative projects and the combination of iterative creative and evaluative processes. Whilst the image is neat and tidy, in our exploratory, transdisciplinary research project, the data collection and analyses were much less linear and predictable.

FIGURE 2. **An adaptation of a Mixed Methods Action Framework**



Research sites

The project was based in Newlands Intermediate School and Avalon Intermediate School in the two classrooms that had the Apiscope positioned in them. These are the only two classrooms in New Zealand that have an Apiscope. The installation of each Apiscope, developed by Professor Jean-Pierre Martin of the University of Orléans (France), and re-designed for teaching and learning in a New Zealand context, was supported with funding from Massey University and the New Zealand French Friendship Fund (NZFFF).

Research participants

Student participants were learners in two intermediate (Years 7 and 8) classrooms across 2 school years (2018 and 2019) at Newlands Intermediate School and Avalon Intermediate School. All students in each classroom, across both years, were engaged in teaching and learning about bees, and this was critical for the collaborative component of the creative process. Also, when the project commenced in 2018, with a phase of diagnosis and reconnaissance designed to get to know the students and teachers, all students were invited to participate in the study. As the project progressed to the phases of planning and implementation of differentiation, particularly at the end of 2018 and throughout 2019, the research participants were students identified by their teachers as kaitiaki for the bees and priority learners.

Table 1 provides a summary of research participants in different phases of the study. As it shows, teachers, and experts, including a beekeeper, artists, and writers, also participated in the research. In 2018, there were 24 students in the Avalon Intermediate School class (38% Māori, 28% Pacific, 24% Pākehā; 13 Year 7, 11 Year 8) and 31 in the Newlands Intermediate School class (13% Māori, 3% Pacific, 84% Pākehā; 18 Year 7, 13 Year 8). In 2018, five student leaders, or kaitiaki, were selected by the Avalon teacher and four were selected by the Newlands teacher. In 2019, the Avalon kaitiaki were in Year 8 and continued in the role. The Newlands kaitiaki had moved on and a new group of four leaders were selected. In addition to these student participants, selected primarily for their leadership potential and skills, each teacher also identified an additional student with other special learning needs as priority learners.

TABLE 1. Research participants by cycle

Participant type	Cycle type and participant numbers				
	Reconnaissance Cycle 1	Planning and Implementation Cycle 1	Reconnaissance Cycle 2	Planning and Implementation Cycle 2	Planning and Implementation Cycle 3
Student	24	-	-	-	-
Teacher	2	2	2	2	4
Student leader	-	-	9	9	9
Artist	-	-	-	-	6
Beekeeper	-	-	-	-	1

Ethics

A full application was submitted to the Massey Human Ethics Committee on 13 March 2018, with approval granted (Southern B, Application 18/05). For the purposes of this report, the researchers, teachers, and experts are named, with their consent, and pseudonyms are used for students.

Data collection and analyses

The data collection methods that were employed in this project are summarised in Table 2. To explain the rich data that were collected and analysed, these methods are described further in the following section. Differentiated responses were central to the iterative processes of action research and demonstrate the use of evidence to inform teaching and learning, as well as teacher development. These differentiated responses included professional learning and development for the teachers during Planning and Implementation Cycle 1; workshops for teachers and students with beekeepers and co-design of creative projects between artists and teachers in Cycle 2; and workshops with teachers and STEM to STEAM projects with students in Cycle 3.

TABLE 2. Summary of data methods by cycle

Data collection method	Reconnaissance Cycle 1	Planning and Implementation Cycle 1	Reconnaissance Cycle 2	Planning and Implementation Cycle 2	Planning and Implementation Cycle 3
Formal student assessments	✓				
Student interest assessments	✓				
Classroom observations	✓			✓	✓
Teacher focus group	✓	✓		✓	✓
Student focus group					✓
Student leadership teacher nominations			✓		
Teacher interviews					✓
Observations of artistic processes					✓
Evaluations of artistic products					✓

Reconnaissance Cycle 1

The first cycle of research was an important step in getting to know the students, teachers, classroom, and bees. The key purpose was to determine the ways in which we might differentiate teaching and learning and link innovative creative arts methods and processes to the strategic focus and curriculum priorities of each school. This part of the study was driven by the teachers who analysed formal assessments of their students, incorporating standard measures, including:

- Progressive Achievement Tests (PATs)—Mathematics, Listening Comprehension, Punctuation and Grammar, Reading Comprehension, and Reading Vocabulary
- STAR Reading
- writing samples assessed using e-asTTle
- NZCER's Science: Thinking with Evidence.

The teachers analysed these results for individual learners and the whole class to determine strengths and abilities, and also to help identify priority learners.

However, as a team we were cognisant of the limitations of standardised tests (e.g., low ceilings, cultural bias, and limited academic focus) and, specifically, the lack of direct relevance in assessing students' specific knowledge of bees and the key competencies necessary for collaboration. The teachers designed rich assessment tasks in discussion with the creative practice and education researchers:

- a mindmap to determine what the students knew, thought, and felt about bees
- an observational drawing activity to assess students' recall of bee physiology from their observations in the hive
- the *My Way Expression Style Inventory* (Kettle et al., 1998) to understand the students' preferences for differentiated products (e.g., verbal, visual).

Student and classroom profiles were developed from the data with the intention of using these as a basis for differentiating teaching and learning. In 2019, these same methods were used with new students in each classroom.

Multiple informal classroom observations (four to five in each classroom) were also conducted by the researchers in these early phases of the project to determine the ways in which teachers differentiated their teaching across all subject areas. These observations then became the subject of a focus group discussion to determine areas of teacher professional learning and development and additional teaching support required for creative projects related to bees. While each teacher's knowledge of their students individually was an observed strength, an observed weakness was a lack of differentiated responses to learner differences in abilities, qualities, strengths, and interests. Also, both teachers were grappling with how they might best use the Apiscope as the centre of teaching that was differentiated in content (e.g., complex, interrelated, conceptual themes rather than "bee" content) and how then to employ artistic processes. Both teachers lacked confidence and knowledge about bees, and, specifically, bee health. As one teacher explained, "... all that content, where can the kids come on at, you know some of them don't really need to know real basic things, I mean that comes down to a teacher having to know a lot of stuff".

Planning and implementing Cycle 1

The first phase of action was focused primarily on the development of teacher knowledge through professional learning and development on differentiation, delivered by an external learning and development provider who visited each classroom and then tailored a 2.5-day programme for the teachers. The teachers engaged in four workshops focused on content, process, and product development.

Reconnaissance Cycle 2

In late 2018, planning of differentiated arts projects had to be abandoned as both colonies did not survive the winter and this event shifted our thinking quite dramatically. A second Reconnaissance Cycle was undertaken, as we began planning more proactive care and monitoring of each school's Apiscope. Action research enabled us to shift back into a diagnostic phase of identifying four to five student leaders in each class who would act as kaitiaki for the bees. An identification form for leadership was created to help identify each student leader's strengths in learning, communication, contributions, and science, and this was completed by each teacher.

Planning and Implementing Cycle 2

Two workshops were developed for teachers and kaitiaki, co-facilitated by Anne Noble and local beekeeper John Randall. These workshops focused on bee health and Apiscope care. The second workshop involved suiting up in bee suits to transfer the new colonies into each hive. Both teachers worked with the kaitiaki to design observational methods and record keeping based on individual strengths (e.g., photographing, drawing)

to monitor bees. In early 2019, Jay McLaren-Harris of Tumeke Enterprises facilitated a 1-day leadership workshop for the kaitiaki from both schools, held at Massey University's Wellington campus. The Years 7 and 8 Avalon kaitiaki attended the training and the Year 8 Newlands kaitiaki attended. The focus of the leadership development was on teamwork; building effective, creative teams; understanding ourselves as leaders; and exploring leadership themes.

Planning and Implementing Cycle 3

The next planning phase began in early 2019 through workshops with each teacher to discuss differentiated whole-class projects for development and implementation in Terms 1 and 2 2019. In both workshops, we were searching for ways that would enable differentiation and support a STEM to STEAM approach focusing on storytelling about bees and an environmental theme. These workshops were held individually with each teacher and followed on from work we engaged in during 2018, our understandings of each teacher's interests, and known characteristics of students in their classes. The Newlands Intermediate School workshop pursued a literacy project to enable differentiation, involving illustration, writing, book design, and production, and linked to the school's sustainability themes. The workshop aimed to model writing and illustrating a book as a potential opportunity to build students' strengths and interests by exploring the process for creating children's books with a children's book author and illustrator, Dr Caroline Campbell, a Senior Lecturer at Massey University.

Similarly, the workshop for Avalon Intermediate School focused on the development of a song writing and music video production project. This project would enable differentiated content about bees and related themes, explored through observations (visual and aural) and expressed through writing the lyrics and composing the music for an album of songs to be created, produced, performed, and marketed by the students. To enable us to explore the song writing process, we worked with Warren Maxwell, a senior lecturer in commercial music at Massey who has made a significant contribution to Aotearoa New Zealand music as a multi-instrumentalist, composer, and Trinity Roots frontman. (Each school's projects are described in the report section called STEM to STEAM projects.) At the conclusion of this cycle, focus group interviews were held with each student project team and the artists. Individual interviews were conducted with each teacher.

Evaluation

Ongoing evaluation of the effectiveness of differentiated teaching and learning was primarily through focus group interviews and discussions with teachers and students (held in each phase of planning and implementation), as well as ongoing informal classroom observations. Because of the nature of action research, and, specifically, the evidence of learning expressed in the outcomes of the creative projects, we were able to continuously feed ideas for differentiation into teaching. The action research model also enabled us to act upon many changes experienced in each classroom during the project; colony loss, staffing changes, and student changes meant that we had to be fluid, flexible, and responsive as researchers. Using action learning approaches also enabled the teachers and researchers to review the perceptual and experiential learning taking place during the creative process.

Data analysis

Data analysis was iterative and ongoing, as is necessary in action research projects to enable data from observations, discussions, and interviews to inform actions. In other words, as data were collected and patterns observed, these were discussed with the team to guide decision making. This is because, in action research, the emphasis is more on *what* practitioners do than what they may say they do. Similarly, creative arts researchers make contributions to the practice-knowledge of the communities with whom they work. Thus, the primary analysis was one of "sense making", primarily driven by the themes of differentiation—searching for evidence of content, process, and product differentiation in teaching and learning. For example, the informal observational notes of differentiated teaching were analysed deductively, based on these theoretical concepts of differentiation, so as to feedback to the teachers and design professional learning and development. On

the other hand, focus group discussions and interviews were transcribed and analysed for key themes that emerged from the data. Data on individual students, as collated on profiles, were interpreted and expressed as case study narratives which provided a detailed description. From those descriptions, we were able to identify patterns and emerging themes of change. It is important to state that, by embedding creative arts approaches, we also adopted the important and valuable perspective of learning through doing—as educators and artists.

Research limitations

It is important to explore the research findings and implications against the backdrop of our project's methodological limitations:

1. No research paradigm agreed at outset. As researchers, we learned a lot about trans-disciplinary research as we set out to explore working together as creative artists and educational researchers. We each brought our different paradigms into the work which enabled and challenged each researcher and practitioner to stretch beyond our “comfort zones”.
2. Lack of shared understandings of the roles of team members. The exploratory nature of our project meant that there were different understandings of the way creative outcomes can be used to reflect on learning and its expression. There were also difficulties aligning the data gathering requirements of the educational researchers with the creative arts approaches that involved a lot more learning through reflecting on creative processes and outcomes.
3. Teacher and project isolation. The project focused on two teachers who had classrooms with Apiscope installed physically based on health and safety for the bees and the school community. Location in one classroom limited engagement with other teachers in their individual schools and ongoing, regular interaction with each other.
4. The restrictive nature of mixed methods action research. Ivankova's model of mixed methods action research was too restrictive, especially as the research unfolded, for the questions we were seeking to understand. The way we used the model more closely reflects Ivankova's updated model (Ivankova et al., 2019) which enables the influence of mixed methods research across all aspects, and also highlights ongoing dissemination, adaptation, and development of evidence-based practice.

STEM to STEAM projects

This section describes the two projects undertaken in 2019 in the second acting phase of our project: the transformation of scientific content into collaborative, artistic products using a variety of observational skills. These are descriptions of the projects, included in the report to enable readers to understand the creative processes.

Newlands Intermediate School Literacy Project

The class decided to produce children's books about bees. The books were intended to be creative expressions of their learning resulting from the observation of the bees in their classroom Apiscope. Five teams of writers and illustrators were formed and each team wrote and illustrated an original story for younger children to help them learn about bees. For this project, the students engaged in authentic book production processes. The books are available in hard copy from the school or as PDFs.

Five books were published with mentoring from scientist and novelist Tracy Farr, illustrator Dr Caroline Campbell (Massey University), artist and beekeeper, Distinguished Professor Anne Noble, and mentor beekeeper Mr John Randall who led several workshops with the whole class.

- Anne and Caroline focused on children's books, visual storytelling, building narratives, and illustration styles.
- Tracy and Caroline ran workshops on how authors and illustrators develop their ideas.

- Anne and John led a special focus on addressing questions to expand students' bee knowledge related to their stories. There was a tessellation project in the morning which explored the rationale for the use of hexagons in the hive through a hands-on polygon building exercise. This resulted in lots of good questions and answers about hive architecture and engineering.
- Tracy and Caroline led a workshop on design layout (concertina style) and offered one-on-one book team consultations with author and illustrator.
- Anne led a team to investigate and manage book production.

At the culmination of these workshops, it became clear that the teacher and students wanted to embark upon more authentic production of a book. Beginning in Term 3, a select group of students worked with Caroline and two undergraduate students on the design and layout of the books, and Tracy provided editorial guidance. Two students worked with Anne as production managers. A group of four students, accompanied by their teacher, visited the printer to observe the printing and binding process first-hand. These students, with the support of their classmates, then went on to co-ordinate fundraising efforts to cover the costs of seeing the books through final production. These roles reflect differentiation to some extent in terms of having select groups of individual students working towards a shared objective—though the teacher selection processes were not well articulated in terms of matching strengths to tasks. At Newlands, the students were grouped and then regrouped for differentiated learning, and this reflects some flexible grouping as an approach to differentiation. A celebratory book launch for the Newlands community occurred on 16 October with over 50 students, whānau, staff, and supporting workshop experts attending.

Avalon Intermediate School Music and Videography Project

The class decided to write songs, produce an album, and create music videos about bees as creative expressions of their learning resulting from the observation of the bees in their classroom Apiscope. Teams were formed, based on student interests and talents, and each team wrote and produced an original song as part of the album, *Yellow Black Nation*—an album of eight original songs. The class also produced several music videos—with teams of student cinematographers, dancers, interviewers, lighting and audio specialists—and a book of lyrics with original student photography (Appendix 4). The album can be downloaded online.¹ A documentary of the process, that included contributions by students who took the roles of photographers and cinematographers, is available online.² There are also music videos and interviews with teachers and students on the Avalon Intermediate School website.³

The students' work reflects high levels of differentiated, authentic processes and resulted in external awards—with the song *Heart and Soul* winning the Bee Aware Month Primary Schools' Video Competition. The ApiNZ chief executive reported that “the high calibre of entries from schools across New Zealand made judging difficult” but the video from Avalon Intermediate stood out because “it showed fantastic creativity and talent from the students, but also, importantly, there was lots of information in there too ... The students had obviously worked really hard to learn about bees and share this information in a fun and entertaining way” (Skerrett, 2019).

The Avalon Intermediate School class was led by Mr Simon Flockton, who was the classroom teacher working with us to establish the direction the project would take. Simon left the school for a new position as the creative production was about to begin, so the overall project co-ordination of teaching was led by Mr Paascalino Schaller with Ms Vicky Harrison, the new classroom teacher. The students were supported by musicians, Mr Warren Maxwell, Mr Solomon Crook, and Ms Maxine McCaulay; photographer, Mr Chevron Hassett; artist and beekeeper, Distinguished Professor Anne Noble; designer, Associate Professor Anna Brown; and mentor beekeeper, Mr John Randall. The students worked with experts and their teachers in weekly workshops over Term 2 and produced their final album. They also created a lyrics book which is available in hard copy. The

1 <https://soundcloud.com/user-227637552/sets/yellow-black-nation/s-a7Qtz>

2 https://www.youtube.com/watch?app=desktop&list=PL4uX5dejA3AyK_xERqxEsUW_v8IMv5mDQ&v=REILp1P818Y&feature=emb_title

3 <https://www.avalonintermediate.school.nz/our-news/yellow-black-nation-project>

album launch was hosted by the students for their whānau and friends on 27 August with about 50 people in attendance. Their work was celebrated on national media, with a Radio New Zealand feature, *Getting Students a-buzz About Bees with Beats* (Johnstone, 2019) and an *Education Gazette* article (Education Gazette, 2019).

The workshops were not whole-of-class; rather, different groups of students worked with different experts depending on the task at hand. Importantly, the students took on professional roles that they identified based on their strengths and interests—lyricists, singers, sound engineers, musicians, rappers, etc. A group of photographers emerged and they worked on still and video imagery to support the video and book production. The kaitiaki played key leadership roles throughout the process, especially as spokespeople for the album release, documentary, and media interviews. These roles reflect differentiation that is based on individual strengths, but also that brings these together for a collaborative effort.

Key findings

Within this section, the findings of the study are shared in relation to each of the research questions.

How can teachers use an observational beehive to stimulate the design and implementation of differentiated teaching and learning?

We found that teachers can use an observational beehive to stimulate the design and implementation of differentiated teaching and learning in different ways. Through this project, we observed three distinct forms of classroom differentiation: student-led differentiation; teacher-led differentiation; and differentiation that arises when a responsive learning environment is created. In both classes, the observational beehive worked most effectively in a responsive learning environment as a centrepiece for an enriched, expert-led collaboration. Having expert artists and beekeepers working in and out of the classrooms led to a level of authenticity in content, processes, and products that responded to each learner's strengths and interests, as the case studies exemplified. The Apiscope itself created authenticity for differentiated learning in terms of its care and observational use.

Observations of teaching demonstrated that, at the beginning of the project, the teachers were enacting what we observed to be “student-led differentiation”. In other words, the students were often given choices in terms of who they worked with, an activity they engaged in, or product they created. The choices students were given provided for variety, though often this was of rather limited variety. Also, our observations demonstrated the beehive being used primarily for whole-class teaching, with very little differentiation in response to individuals or groups of individuals with shared interests or strengths.

The teachers in our study did not engage in teacher-led differentiation whereby data are analysed about individuals or groups of students—at least not in observational learning from the beehive. Professional learning and development, the creation of learner profiles, and interpretation of data by an educational researcher were interventions intended to change teacher behaviour and enable differentiation. These interventions were not, however, effective in assisting the teachers in using the observational beehive to stimulate design and implementation of differentiated teaching in the arts in response to individual learner differences. The professional development was interpreted by the teachers as being for a specific group of learners, and not applied throughout the classroom. Engagement in a research-based conference was reported as “a bit dry” by one of the teachers, and while “interesting to understand the theory better” there was a perceived gap between research and practice. This may explain why the data analysis interpreted as learner profiles was not used by the teachers, but it is also noted they had their own developed practices that informed differentiation (e.g., a spreadsheet of skills).

The STEAM projects—books, videos, and music about bees—required and developed varying levels of bee knowledge. The students, in their final focus group discussions, reflected their learnings about bees that could be categorised as physiological, in terms of understanding bee biology, and also behavioural—understanding

how bees communicate, work, and live together. The students' writing in both books and lyrics also reflects their understandings of human relationships with bees. As one of the students said: "Before this, I was like why do we even need them? They're useless. And then ... I learnt about it, what they do for us." Another student expressed a greater appreciation for bees, saying: "I have always loved bees but now I love bees more because of this book."

The processes of creative song writing, composing, and music video production provided authentic learning experiences that many students reported as novel, challenging, and engaging. The artistic and music production followed creative processes that required working collaboratively to problem solve and co-create solutions. In complex projects like bookmaking or musicmaking, no one individual can create the final product, and, as Anne explained, "It's kind of modelling how collaboration functions in real life ... they were able to be a part of creating something that no one person could do on their own."

Part of this authenticity was reflected in the equipment, processes, programs, and editing. The students used computer programs, like GarageBand and InDesign, as well as equipment including 35mm cameras, sound recorders, and instruments. All of these tools required learning about how to use them, which one student described as "kind of hard" making reference to the teaching he received from an expert photographer about how "when you take a photo you have to do it at different angles". Another student explained that: "There's a lot more that goes into book production than you think about ... It's a lot harder than you think." Creating songs for an album or writing and illustrating a book were new experiences for most students. When they had some past experiences, these were not modelled on authentic song writing or book production processes as in their STEAM projects. One student explained: "I had actually made a book in primary once but like it wasn't like this, like doing all the printing and stuff ... This book process was hard. It was exhausting." Another student said: "This is more real."

As one of the artistic experts described, the students

... learnt about real life processes, you know really in a rich way and in a really authentic way. I don't know how you would assess that other than the success of the whole thing but that was an absolutely enormous amount of knowledge, experience, work, burden that those students took on and I don't know how you can assess it or reward it, but it is huge.

Part of the enormity of the tasks was the multiple components of the products students were creating. For example, one of the students in the group who created the song *Heart and Soul* said the products for the song were "the beat, the lyrics, the rhythm, the rhyming words, the dance moves". Differentiation came to the fore through these creative production processes, with the Avalon Intermediate School students, in particular, initially deciding their areas of interest in roles as producers, lyricists, choreographers, and so on, but over time broadening and expanding these roles with some flexibility and fluidity.

Being creative in the transformation of content into products was also enabled by a range of authentic learning environments and resources. Each classroom used the Apiscope for observation of bees and maintaining the health of the colony, but also for observations of bee physiology and behaviours. The students' observations informed their writing; as one student explained: "by looking at it and imagining the types of jobs that were going on". The Apiscope was used as a tool to teach drawing and photography. Another important use of the Apiscope was for the development of leadership skills and responsibilities, with the kaitiaki monitoring health and communicating with others about bees. Being able to communicate their learning about bees to visitors in the school was especially important for the Newlands Intermediate School students who enjoyed opening the observational hive for others. But the Apiscope was not front and centre of learning; rather, it was one of many tools used for learning about bees. An Avalon Intermediate School student told us: "We just feel like it's not even there. We're just happy that we learned about the bees and turning it into songs."

The kaitiaki and other student leaders who emerged in the projects also enjoyed other authentic learning environments; namely, the home of a beekeeper, the university's recording studios and College of Creative Arts, and the printer's workshop. At the beekeeper's home, the students "suited up" to transfer bees into their

Apiscope (following the colony collapse), to learn about bee health and care, and to record sounds of bees and the sounds of their hive for their albums (e.g., the buzz of bees). The students from Avalon Intermediate School enjoyed these tactile learning experiences, and, as one of the boys said: “I learned how honey tastes ... I was face to face with the queen bee.” The university recording studios gave students the chance to “play different types of instruments”, and the visit to the printery was described by Jared, the teacher, as “taking the thing to an authentic context actually producing something”.

The content, processes, and products of learning were differentiated throughout the project, and this was most evident through the creation of books and music. As Anne explained:

We structured an art project centred around differentiation. Art as a mode to express learning is difficult to measure in traditional ways but there is evidence in the outcomes of high-level literacy about bees expressed creatively in the drawings, the lyrics, and the recorded oral performances.

The creative arts offer the opportunity for experiential and perceptual learning which can be analysed through reflection on the learning evident in the creative outcomes. Discoveries raise further questions. The outcomes of high-level learning are generated through practice and in both these projects through the collaborative making process. Surprisingly, high-level literacy, for example, can be evidenced in the outcomes themselves—in the case of Avalon Intermediate School, both in the lyrics, but also the spontaneous oral performance of lyrics across a range of musical styles.

Does differentiated teaching and learning with the Apiscope develop and enhance students’ knowledge, skills, and attitudes?

Our project’s findings provide insight into how learning with an Apiscope can facilitate changes in students’ knowledge, skills, and attitudes, particularly from a collective perspective, across sciences, mathematics, literacy, and the arts. We also found that learning with the Apiscope provided rich learning opportunities for developing “key competencies” (Ministry of Education, 2007, p. 12). Using the creative processes of video production, as one of the teachers explained, gave students opportunities to develop through “the key competency of managing self, or through their language, their English skills in the poetry that they’ve written, their art skills, the way in which they’ve explored visual ideas, or you know science, I mean there’s tons in there.”

It can be, however, very difficult to measure individual growth in a collaborative, artistic project, in the same ways that one might assess changes in other educational interventions—and this conundrum plagued the education researchers throughout the project. What became more and more evident as we implemented the project was that engagement in the production of authentic, creative products, which positioned arts across the disciplines, meant we had to negotiate some complex issues. For example, the assessment of learning by individuals was a challenge, because, as Anne explained:

Art is not something that’s just a means for individual expression. Our project demonstrates that art and creative processes used as means to express learning about bees in a number of subject areas supports differentiated interdisciplinary learning and results in rich cross-curricular literacy, numeracy learning outcomes—in quite surprising ways.

An analysis of the books and albums by the artists demonstrates learning in bee knowledge, artistry, literacy, and numeracy, evidenced to varying degrees by different groups of learners.

Literacy is strong in the projects as evidenced in the use of language, rhythm, sentence structure, and imagination. For example, rap is used to explore complex concepts: “Bees are important, they pollinate. We are destructive, we propagate. As our world dies we affirm one fate. The death of bees in the death of this place” (*Yellow Black Nation*). Rhymes express roles in *Meet the Bees* using an ABAB rhyme scheme and imperfect rhymes: “Their job is to care for the cells. They also help with little larvae and pupa. They do this job very well. I think their job is super.” One of the writers talked about getting better at rhyming as a story teller: “Eggs. Legs. Rhyming schemes, rhythm and complicated words.” Another student said: “I guess I got better in the rhyming part, just a bounce of word

play.” The students also used different types of writing within and across their books; for example, *Little Bees* used a glossary to include facts and *Bonnie the Bee* used a three-tiered narrative of facts, a journey, and jokes. Creating rhymes meant the need for fact checking—for example, sounds good but is it accurate?

Science knowledge was developed and evidenced primarily through bee knowledge that was both broad and specific. For example, the lyrics of the song *Yellow Black Nation* express not only an accurate understanding of the social life of bees, but also the interconnectedness of living systems. In the book, *Attack of the Varroa*, and the song, *Nemesis*, the students express good understanding of the challenges and threats to bees. *A Bee's Life* demonstrates understanding of the complex life of the hive and the complexities of bee roles. At times, though, the final products included some misunderstandings. For example, in the book *Ten Little Bees*, while the threats of wasps and varroa are accurate, the story shows superficial and incorrect knowledge, with a bee being chased by a thrush. Some of the story books, in particular, revealed incorrect information related to the honey bee with a New Zealand context that points to the use of limited internet sources rather than direct observation of the classroom Apiscope to support their learning about bees. For example, in the main learning activity about bee roles, which influenced the content of most books, the students were given a limited choice of websites to visit for information. The images of beehives drawn in some of the books were also sourced from the internet and lacked knowledge about bees within a New Zealand context.

Using the internet, as opposed to spending time observing bees in the classroom Apiscope, was not the method of observation-based learning that we hoped the students would engage with in developing content knowledge. While it is not unusual to conceptualise learning as based on what one reads in books or online, the Apiscope provides a model for learning through systematic observation that is used in both scientific and creative inquiry—as a stimulus for curiosity, asking questions, linking experiences with new encounters, gathering information, finding patterns, or observing relationships. Observing the roles, habitat, and behaviours of bees in the Apiscope might have been used as a starting place for further investigation using books, the internet, interviews with beekeepers, or other sources. Students could be better supported in observation-based learning by their teachers who may require direct instruction in how to facilitate observations that are systematic, reflective, recorded, and analysed.

Mathematical knowledge is explored through tessellations in the illustrations of several of the books—*Attack of the Varroa*, *A Bee's Life*, and *Meet the Bees*. The tessellations developed from a classroom project led by Anne and John, the beekeeper, whereby the students built their own structures using three-dimensional paper hexagons. This project developed understanding of the strength of a hexagon by building and testing comparative shapes and asking the question: “Why do bees use a hexagon shape and not a circle or a square?” Students identified relationships to engineering, that diagonals provide strength in an architectural structure. This was authentic learning rather than a pattern identification exercise. By contrast, a very simple counting technique is effectively used in *10 Little Bees*. In the songs, maths was applied through the development of simple and complex beats. These examples of literacy and mathematics in isolation of one another do not show tremendous leaps and bounds in learning, but when put together in the production of a book or song lyrics and video, they show an application of knowledge and skills that is more complex and abstract with real-world relevance.

The artistic skills demonstrated were also noteworthy, with perspective being a key area of strength development. As Caroline explained, the aerial perspective of the queen bee, as illustrated in *Attack of the Varroa*, was an approach “even my [university] students wouldn’t necessarily think to do”. The books also brought interesting perspectives on bee life to the design, text, and layout. Similarly, perspective was brought into some of the photography work. Anne described one of the students as a “portraitist” who was “able to perceive and express qualities of relationships in exceptional ways”. In a more abstract way, perception was addressed in the lyrics of *Ultraviolet Light* which provided an imaginative response to the complex vision of bees.

Key competencies were developed throughout the group work as students collaborated within and across teams. They developed skills of relating to others, managing self, and participating and contributing. For example, being part of a collaborative, creative process meant that students had to work on their listening skills as they negotiated and shared ideas for their books or albums. Students developed self-management skills by

working to deadlines, communicating with adult expert artists and beekeepers, taking risks as they learned new skills, and understanding there is not one, right answer in creative processes and outcomes. As Vicky, one of the teachers, expressed: “I think very much ... the key competencies ... like the group work, and having to negotiate within a group, how the direction of something is going to go, that was a really big one for them, and then having to support each other in the roles, to actually achieve where they got to.”

The teams had to work together in an intense, highly productive phase of work that Caroline, the author-illustrator, described as “an enormous amount of learning that they had to take on and work their way through in a very short period of time in addition to doing all the other learning that they had to do with their curriculum”. One of the students at Avalon Intermediate School told us that she was “more organised and directing” which she found “fun” during the production process. Another student expressed a greater sense of cohesion with classmates, saying that “we got to spend more time together as a class doing something different and something we all enjoyed”. One of the Newlands Intermediate School students perhaps best summed up their growth in key competencies:

We learnt about how to contribute as a group and put something together that is going to be used in the future. We learnt how to come up with ideas and talk to each other and just communicate better ... How to share ideas and agree with communicate with each other when things don't go our way. Making sure everyone gets a say while having fun.

What is the relationship between differentiated STEAM teaching and learning, and changes in the knowledge, skills, and attitudes of priority learners?

We concluded that, for some learners, individual learner profiles and case studies best illustrate the relationships between differentiated STEAM teaching and learning and changes in knowledge, skills, and attitudes. During the project, we identified six case study students whose profiles have been described and interpreted to demonstrate the impact of differentiation. To protect the students' privacy, the case studies have not been included in this report, but an analysis shows a clear relationship between the differentiated teaching and learning around the beehive through creative production and changes in priority learners (e.g., those with gifts and talents, from different cultures and socioeconomic backgrounds, and those with disabilities), as this section will describe.

Each case study student showed growth in their strengths and abilities through their engagement in the differentiated learning opportunities facilitated through the creative processes of book or album production. The most growth and confidence was evidenced when the specific activities in which they engaged were well matched with their abilities and interests, which each learner was able to clearly identify and articulate. For example, Manaia had exceptional abilities, and, for them, growth came from challenges, such as being asked to step up into leadership roles or push what they may have perceived as their upper limits of ability. Manaia's teacher noted that he was “good when speaking to others, although slightly nervous”. Following the leadership training, Manaia explained that his confidence had grown from “an amount of 45%” to “around 70%”. He was described by his teacher as a “quiet and deep thinking student” who could improve his verbal articulation and presentation; Manaia confirmed this on reflecting on his leadership learning by stating that if given the chance “to speak in front of others, I'll take that opportunity”.

However, there was limited growth for students whose abilities were not well understood or developed with content, processes, or products that might have been challenging for them. For example, Ru was a highly academic and competent student, with high reading and mathematics assessment (e.g., STAR and PAT at level 8). Her teacher described her as an “exceptionally keen learner, always willing to give new things a go”. Ru did not find the book production academically challenging, stating that: “It's okay. We haven't really been doing much and everything is quite chill and easy.” She also described her leadership role in the book production as lacking in challenge, stating: “sometimes you had to kind of lead but most of the time it was okay”. Ru indicated some growth in leadership in terms of “trying to put all ideas from each person so no one is left out”. On

reflection, Ru's skills and abilities (academically and socially, in terms of leadership) were not well understood or developed in the project. Her bee knowledge developed, as seen in her engagement in their daily care and sharing, but she was unable to articulate detailed facts and information, and she was not seeking deep understanding of concepts related to bees.

Using multiple ways of gathering information about individual students and collating those in a succinct profile has the potential to better ensure that students' abilities and qualities are identified and developed through differentiated teaching and learning. The formal assessment undertaken by teachers during the reconnaissance phase of this project was limited to knowledge and skills in literacy and numeracy, and, whilst this information helps teachers understand potential in those areas, it is not an accurate reflection of broader abilities and qualities needed for successfully undertaking STEAM projects. For example, Moana's formal assessments gave no indication of her observational abilities, which enabled her to take insightful, interpretive photographs of people and bees. If teacher decision making about STEAM differentiation had been limited to traditional, formal pre-assessment of knowledge and skills, some students, like Moana, would possibly have been overlooked for their exceptional abilities and qualities. In this project, abilities and qualities were also detected by artists and practitioners in creative processes, who very ably created differentiated learning opportunities that enabled strengths and abilities to make themselves known to observers. For example, Anne assessed a photographic contact sheet of Moana's and described Moana's process as "quite remarkable" and demonstrating a "kind of visual intelligence" that is often not seen in first-year university photography students.

The differentiated STEM to STEAM approach additionally supported the development of confident, creative individuals who grew in their ability to contribute to team learning. Awi, for example, was selected as a kaitiaki by her teacher because of the potential he saw in her ability to lead, especially given her strengths in communication and her respectful way of engaging with others. However, in the initial stages of the project, Awi was very challenging to engage in participation, and, as one of the researchers observed, "definitely did not want to participate". However, based on her self-identified interest in photography, she was invited to be a photographer and when "given a camera and encouraged and shown how to operate it, she loved the role of actually being behind the camera and being part of a project contributing to it as an interpreter" (Anne Noble's observation). As the project progressed, Awi became more competent with the camera and began leading others; in fact, "others would gravitate towards her and work with her when she wanted something set up or needed help" (teacher interview). This transformation from a quiet, perhaps even withdrawn, student to a class leader who directed and edited videos was noted by all teachers and researchers who engaged with Awi.

In some cases, the students led and supported others' specific and differentiated contributions to collaborative creative projects. Ruth, for example, was challenged by managing others in a group, especially in the final production stages when she identified "lots of strong personalities" in the group. She also felt that she talked too much, but her communication skills served as a strength in the ways in which she was able to communicate with the teacher, artists, printer, students, and others in the school community to lead the production. Ruth learned about

real life processes, you know really in a rich way and in a really authentic way. I don't how you would assess that other than the success of the whole thing but that was an absolutely enormous amount of knowledge, experience, work, burden that those students took on and should and I don't know how you can assess it or reward it, but it is huge. (artist interview)

Similarly, Awi took on roles in videography editing that enabled her to fulfil her desire to communicate her work, and also enabled her engagement in the project in a way that felt comfortable for her. What happened was described by her mentor photographer, Anne, as a "complete transformation" to a student who seemed to "develop some sense of self, confident in her abilities".

In all cases, the students gained knowledge and skills through learning with, from, and about professional artists and beekeepers. Manaia, for example, explained that his interest and knowledge of bees in early 2019 had grown, but his teacher indicated that he needed to continue to develop "good observational skills and diligence with checking the hive". By the end of the project, Manaia explained in an interview: "We check on the

bees, how the honey is doing, and then for a bit we look for the queen and the varroa mite.” Throughout the project, Manaia recognised the need for more information, and he was often seeking conceptually challenging knowledge. For example, in May 2019 he was searching for “more information on how honey bees affect native bees” and “the history of the honey bee ... some secret about it or facts that not many people know about”. Manaia was also mentoring another student as a Year 7 who would look after bees in Year 8.

As the changes we saw and describe above show, there is benefit in the facilitation of differentiation by people with different expertise who can offer content, processes, and product development that support teachers in their practice. It was agreed that, rather than taking the teachers out of their classroom environments to develop artistic expertise, artists and experts would be brought into the classroom to work with the students alongside the teachers. This was described by Jared, the teacher, as “taking the thing to an authentic context, actually producing something”. When expert artists and beekeepers intervened and led the teaching, differentiation began to take shape. As one of the teachers working at Avalon Intermediate School, who is also a performing and creative practitioner, Paascalino, explained, it takes “multiple different skills to be able to differentiate a programme, in the way that we were doing it”. As the Avalon Intermediate School lead classroom teacher, Vicky, said, she was “on the edge” of teaching and learning—observing and supporting the experts who could take the work to “another level”. This “other level” is essentially authenticity, a depth of content and process knowledge in the real world—and all teachers acknowledged the student products would not have been of the same quality and depth without that expertise. As Jared, the Newlands Intermediate School teacher, told us, “sometimes I feel like I have an impostor syndrome, but I think the best thing was when the experts came in and it was ... beyond my realm of ... expertise and knowledge”.

Implications for practice

Here, we identify and explain four implications for practice that have emerged from our research.

Implication 1: Teacher consideration of the position of arts in the broader curriculum is essential

A major implication for differentiating teaching and learning through STEAM is the need for critical teacher consideration of the position of arts in the broader curriculum. This project positioned the creative arts centrally within the curriculum. Throughout our project we prioritised multi-modal authentic learning about bees through both sensory exploration and structured curriculum activities. Students were then able to utilise this knowledge about bees to innovate, problem solve, and co-operate with peers in complex creative projects that required differentiation of skills and abilities to achieve outcomes no student could have achieved on their own. While art within the curriculum is traditionally seen as peripheral to the curriculum and as a means for students to acquire a subset of skills for individual and cultural creative expression, our project models the benefits of a STEAM education approach that enables the expression of observational and interdisciplinary learning through collaborative creative arts projects.

The creative arts projects demonstrated what is possible when the creative arts are taught within the curriculum as an integrated whole, collapsing the boundaries between visual art, music, dance, drama, and creative writing as separate subjects, and also, when appropriate, collapsing the conventional discipline boundaries—between Art and Science, Art and Mathematics, Art and Social Studies, and Art and Language. Furthermore, the projects demonstrated the benefits of bringing experienced artist/teachers into schools—and the contribution of the creative arts to the development of authentic multi-model learning opportunities and environments is the key to differentiation. It is important that the roles of experts are clear, as otherwise creative projects could potentially become that of the experts/researchers, rather than projects that are co-constructed as artist/teacher partnerships with curriculum innovation and differentiation in mind.

Implication 2: Teacher knowledge and understanding of differentiation principles and how these are applied in practice must be developed

The complexities of creative production enabled us to observe three distinct forms of classroom differentiation: student-led differentiation; teacher-led differentiation; and differentiation that arose within a responsive learning environment where learning was co-facilitated and co-created between classroom teachers, artists, beekeepers, and students. Teacher knowledge and understanding of differentiation principles and how these are applied in practice must be developed in order to see shifts from student-led and teacher-led differentiation to that which is much richer as teaching and learning is developed in a responsive, authentic environment.

The roles of the experts in identifying and responding to individual differences in our project morphed beyond what was initially proposed for exploration. The intent at the outset of the project was for the artists to work directly with the teachers to support differentiated pedagogy; however, the limitations of the study, as described in an earlier section of this report, created an unanticipated shift whereby the experts/researchers were facilitating teaching and learning. Working in partnership with creative practitioners, teachers need to be positioned to move across and between student-led and teacher-led differentiation, and empowered to lead and facilitate differentiation in authentic learning environments. Whilst learners will develop their knowledge and skills by working with creative practitioners, this learning will be more powerful and longlasting if it is sustainable and repeatable by teachers in classrooms.

Implication 3: Robust understandings of researcher roles are required when teacher-led action research on differentiation is supported by creative artists and practitioners

Similarly, from our work together, we believe there are implications for teacher-led action research on differentiation that is supported by creative artists and practitioners. A better understanding of the roles of teachers in leading action research in their classrooms, with the support and engagement of artists working in schools, needs to be developed. We are keen to explore further how artists can work more effectively as partners with teachers who take the lead in designing differentiated learning opportunities. We would like to see teachers exploring creative processes that are new to them in ways that excite and motivate their practice, with the support of artists and artist-educators.

Implication 4: To ensure meaningful curriculum differentiation, resources and support for teaching and learning about living systems must be developed

When observational learning is focused on a living system maintained on school grounds or in a classroom, like the Apiscope, there is a need for the development of resources and support for teaching and learning. For example, in this project we developed protocols for care, including written observational guides; facilitated teacher learning, development, and support from professionals, like beekeepers; created opportunities for student leadership development, training, and support for maintenance and monitoring, linked to important curricular goals; and encouraged enhanced teaching of content related to the living system and the teaching of observational skills. In this project, with bees as a living system, having a beekeeper on site would be ideal.

Conclusion

In conclusion, this project set out to explore how observations of a living system might promote interdisciplinary learning by providing a context for shifting STEM to STEAM. Embedding the arts within the rich content provided by the study of bees through authentic, experiential observational processes facilitated collaboration and creation of artistic products. Integrating the arts into the curriculum enlivened the content, introduced creative processes alongside scientific exploration and discovery, and resulted in authentic, real-world learning outcomes through student exploration of complex living systems and real-world environmental problems. Telling the story of bees with musical lyrics and children's literature and enriched with dance, photography, videography, illustration, singing, and collaboration fed students' natural curiosity about their world and empowered them to explore ways they can change it for the better.

Pī honi, titiro mai

I am precious precious precious

Me tiaki, he taonga

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4 <https://bestawards.co.nz/public-good-award/public-good-award/jia-design-studio/the-new-zealand-apiscope/>