Evaluating the impact of virtual reality-supported teaching on primary student learning

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This project is a collaboration between the University of Waikato, Auckland University of Technology, Sir Peter Blake Trust (BLAKE) and St Peter's Catholic School, Cambridge

Wilf Malcolm Institute of Educational Research
Te Pūtahi Rangahau Mātauranga o Wilf Malcolm
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EXECUTIVE SUMMARY

This report details a collaborative research project involving educational researchers at the University of Waikato and the Auckland University of Technology (AUT), and educators at Sir Peter Blake Trust (BLAKE), as well as teachers and students at St. Peter's Catholic School, Cambridge. In 2018, BLAKE introduced a free Virtual Reality learning programme (NZ-VR) to Auckland schools. This aimed to introduce students to a broad range of ideas about marine conservation (see https://blakenz.org). This collaborative project sought to understand ways to maximise the introduction of VR-supported learning in primary classrooms. The research team contributed expertise in Educational for Sustainability (EfS), digital pedagogy and VR technology to this agenda.

The collaborative project evaluated the impact of introducing VR on students' understanding of EfS concepts and development of scientific observation capability. The aims are encapsulated in the following research questions:

1. *What is the impact of using virtual reality to support primary students' understanding of marine eco-literacy*?
2. *What is the impact of using virtual reality to support primary students' learning of the science capability of observation?*
3. *How can the use of virtual reality be purposefully designed into classroom learning experiences?*

A single cycle design-based intervention research (DBIR) was employed involving a developmental, implementation and evaluation phase with a case study teacher and her students. Data were collected from participants through surveys conducted pre- and post-VR learning experience, interviews, observations, student assessment, and teacher planning notes.

Findings suggest that students' marine ecoliteracy improved after their VR-supported learning experience, as they demonstrated greater knowledge of marine reserves, of overfishing, and or marine pollution issues; positive attitudes towards marine environments, and expressed intentions to act to address the issue of plastics in the ocean. Over the course of the intervention, students showed evidence of improved observation skills, a key science capability. Students reported being able to 'pick up more things' and their observations as evidence. They were also more prepared to deeply consider what they were seeing. An improved expression of biodiversity ideas, interactions between species was also evident between the pre- to post-VR learning observational task.

The project's findings resulted in the following recommendations:

- For VR to be a valuable learning tool there is a need to evaluate the extent VR-based learning might foster authentic, experiential, inquiry-based, game-like learning within a particular learning context. For an immersive experience to be effective it is important to include opportunities for social interaction; which kinds of interaction are most productive also need investigation.
- Consider ways to maximise the impact of working with schools and teachers, suggestions include:
  - Reconsider the value of visiting many schools for short periods as opposed to fewer schools for longer periods.
  - Review scheduling procedures and prior-visit support.
  - Revisit teacher professional learning provision to provide greater support for teachers to explore and employ ways to contextualise learning around the VR resources and the BLAKE educator visit.
  - Be aware of the importance of a VR desensitisation phase.
  - Introduce VR guidelines to maximise VR use for focused learning.

   - Encourage teachers to plan for VR to be part of an inquiry approach and to plan for a follow-up to the VR experience.
- Consider BLAKE educator learning and development (e.g., opportunities for BLAKE educators to develop pedagogical strategies for working with teachers and students; explore partnering with a PLD provider)
- Promote the NZ-VR resource through a variety of avenues to alert teachers and schools to the resource; support teachers to share their experiences to promote BLAKE's VR resource as distinctly NZ based; consider linking with the Science Learning Hub to disseminate exemplars of successful VR-based teaching practice to science educators.

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INTRODUCTION

The project described in this report is a collaboration between educators/staff at Sir Peter Blake Trust (BLAKE), educational researchers at the University of Waikato and the Auckland University of Technology (AUT) as well as a teacher and her class students at St. Peter's Catholic School, Cambridge. The project aimed to evaluate the impact of introducing Virtual Reality (VR) to support primary students' understanding of Education for Sustainability (EfS) concepts and development of scientific observation capability.

In 2018, BLAKE introduced a new free VR-based outreach programme (NZ-VR) to Auckland schools aimed to introduce students to broad ideas on marine conservation (see https://blakenz.org). Teaching resources to accompany the VR learning experience had been developed and are accessible on their website for educators. The programme is conducted by two NZ-VR educators who are in contact with schools and arrange the logistics to conduct the programme with school teachers. BLAKE intends to extend the programme to schools across the country. This collaborative study was an opportunity to obtain additional evidence from educational researchers with expertise in EfS content, digital pedagogy and VR technology to contribute to enhancing and extending the implementation of the NZ-VR programme. For the research team, this collaborative project provides an opportunity to research the introduction and impact of a high-end immersive technology to offer research informed recommendations for VR-supported teaching-learning practice.

The NZ-VR project

The NZ-VR project has been a partnership between BLAKE Trust and New Zealand Geographic (NZ Geo, see https://www.nzgeo.com/). Its genesis has been described by New Zealand Geographic's representative as a "direct descendant of" the multi-agency report released by the government in July 2017, Mātauranga Whakatuka Taiao: Environmental Education for Sustainability (Department of Conservation, 2017). This strategy and action plan was designed to create a step change in environmental education for sustainability (EEfS) for Aotearoa New Zealand. Stimulated by this and frustrated by their own lack of success in delivering effective EfS on a wide scale, they could see that a key missing element was experiential learning. As the representative noted, the project was conceived as a "place-based education project that we wanted to make work at scale. Very few kids will have access to the marine environment …. certainly not pristine environments". Interviews with the NZ-VR educators indicated that for them:

> The main goal about the NZ-VR programme would be to open up people's eyes to what's beneath the surface and having that experience that you wouldn't get otherwise unless you went snorkeling or diving. Being able to take you there, into that environment and seeing for yourself what it looks like. A lot of the time people see the surface, but not what's underneath. So, creating ocean visibility was the main idea behind the programme.

The project focussed on how these experiences could be provided for all New Zealand students to create awareness and empathy for these environments. As NZ Geo's representative described:

> there would be no way that we could send the population of New Zealand to the sub-Antarctic Islands, or Antarctica or to the Kermadecs. Those locations wouldn't physically tolerate that number of people. It's too hard to access. I believe that unless we've had an experience, I don't believe we care about it. We don't care about what happens to our wild places.

The NZ-VR project has been designed to support teachers teaching and student learning of marine ecoliteracy. At primary school level, teachers are generalists and therefore need to have a broad range of knowledge across all learning areas. This can mean that they lack deep knowledge in areas such as science, and in particular about contemporary issues that are developing constantly, and "to compare and contrast between different environments", as the NZ-VR educator explained. To address this, NZ Geo's representative noted that:

> a lot of what we're working on is trying to get teachers' confidence in teaching Science, and many teachers are terrified of it. And yet this gives them an experiential piece that allows them to teach

> these very, very difficult principles of complex environmental science and things with confidence, because the kids understand it.

Tackling these twin conundrums of how to provide experiences without being able to physically visit these environments, and to explore the complexity of natural environments and their associated problems, NZ Geo proposed the use of Virtual Reality as a tool to overcome these challenges. As NZ Geo's representative discussed, "the VR process is about trying to convey some of those complicated ideas in the most visceral way we can. And unfortunately, VR is the best technology we currently have to do that".

While shortcomings were recognised in this approach, the NZ Geo's representative saw that it could provide a productive means to overcome them:

> It does embody experience in a way that words, and pictures, and video ... I mean the closest thing would be that suspended belief when you're inside a movie theatre, and you can kind of forget about your surroundings and be in the environment for a moment. VR is just an extension of that. It's more effective.

The VR experience was seen as a way to 'immerse' learners in an environment without having to overcome logistical and emotional barriers, as one of the NZ-VR educator noted:

> I think that the VR aspect is the closest way people will be able to see that without having to face any fears of swimming, or the gear, or the training, or the cost. It removes all of those barriers.

However, the design team also recognised a limitation of VR compared to reality, as one of the NZ-VR educator explained:

> I think the key thing that I miss in the VR videos themselves is when you're in the water, you connect with the species around you. And so if you're moving your hands the fish are moving either towards you, or away from you, you are more part of that environment. Whereas through the VR you've got more of an observer's kind of approach. You're seeing everything that's going on, but you don't have any influence as such.

Having made a decision to invest in and adopt VR-based technologies, there were other challenges to consider, including whether to use real-life or animation to portray the material. A conscious choice was made to preference 360-degree video rather than computer graphic imaging (CGI), as the NZ Geo's representative explained:

> We chose our 360 video largely because New Zealand Geographic has always tried to make it the most accurate, geographically accurate and compelling experience possible. We didn't feel like we could get there and show a range of places with CGI alone.

Another consideration in designing the project was the need for relevant information technology (IT) infrastructure and in particular, the capability of a school's broadband network. So, a system design was devised to overcome these challenges, as the NZ Geo's representative explained:

> We were completely independent of all of that, and we could choose the video and play it across all headsets. And the unexpected side-effect of that was that it made VR social. Because everybody's video would start on the same frame, and they could see stingray approaching the camera at the same moment. And so suddenly it was social, it was pretty much bullet-proof. It worked the first time, every time.

A key part of the thinking for NZ Geo was to make the delivery as seamless as possible, and to ensure that technological issues were not a factor. The representative noted:

> We're doing everything we can to move technology out of the way of the experience, to make it a frictionless experience for people. They [students] put on their headset, they start the process, they have a very, very rich and compelling experience.

NZ Geo could see elements of development were still possible in the project. These related to refining the delivery of the VR experience and in making the experience more enduring with a wider impact. The NZ Geo representative remarked:

> I would like to be able to leave behind headsets in each location. And you know, high-quality headsets if possible. If not, Google cardboards that kids can take home and use in their own time. I think that 'leave behind' aspect would be a really important part of how to improve on this. Because they have a compelling visceral experience, they want to share it with their friends, they want to replay that experience, they want to take it home and show their parents. The homework part of this is missing, and homework is an important part of the learning experience because it reinforces things that you learn at school.

These virtual experiences were designed to support understanding and action-taking, as one of the NZ-VR educator explained:

> Understanding why those environments are the way they are and the second part was the action. And that's the part where most I guess… That's the most important part, it's not just what the issues are, but it's actually how we can help – what we can do. And those actions, you can't know what to do, if you don't know what the problem is.

The two key marine issues that BLAKE decided to build the VR experience around were overfishing and pollution, as these were easily visually represented. The NZ-VR educator noted:

> For ocean acidification, that is a lot harder to visually see the changes. Climate change–there's parts of it you can teach, but there's parts of it that would be very hard to visually illustrate that. And so, for us, overfishing and pollution were two main ones that we can talk about.

For the one-hour classroom sessions using VR, BLAKE currently employs a form of constructivist teaching to make learning active for the students. The NZ-VR educator explained, "We all do it by questions. Depending on the students, you can ask certain questions that will get them to come to the answer. But it's not us telling them what's going on".

BLAKE was aware of the limitations of offering a one hour, in-classroom session delivery approach, as the NZ-VR educator explained:

> We are only with the class for an hour. I would hope that every single time we have an awesome session, [but] it really needs to be followed up. And it really needs to be led either by families or the school, to have that really ingrained, and like go into further discussion and investigation around them. I think that the VR programme although it's like a great one-hour session, isn't like the whole solution. I think it really needs to be followed on with other resources. And I guess the short way of saying that – that it can't be a stand-alone session to make change.

It was from this background that this study was conceived to explore the educational impact of the NZ-VR project and how the VR-supported teaching and learning experience could be enhanced.

RESEARCH AIMS AND QUESTIONS

The research team conducted a small case study to understand the impact of and ways to maximise the introduction of VR-supported learning in a primary classroom with the aim of informing teaching-learning practice. The research project aims included:

a. **Evaluating the impact of introducing VR** on students' understanding of EfS concepts and developing scientific observation capability, and,

b. Developing relevant evidence-based curriculum resources to **complement, inform and enhance** BLAKE NZ-VR's current resource bank that will be useful to convey/communicate the appropriate and possible teaching practice and approaches to primary-level teachers who are not familiar with VR. This resource is intended to enhance and widen BLAKE's current work and outreach to educators and to students.

The aims were translated into the following questions guiding the study:

1. *What is the impact of using virtual reality to support primary students' understanding of marine eco-literacy?*
2. *What is the impact of using virtual reality to support primary students' learning of the science capability of observation?*
3. *How can the use of VR be purposefully designed into classroom learning experiences?*

RESEARCH DESIGN

The study involved working in collaboration with BLAKE's NZ-VR educators and a case study primary teacher and her class at St Peter's Catholic School. We had chosen to work with a primary school as the literature indicates a scarcity of studies directed at this level and to address concerns regarding primary student engagement and participation in virtual environments (Hew & Cheung, 2010; Pellas et al., 2017; Southgate et al., 2019).

We conducted a single cycle (see Note 1 under Table 1) design-based intervention research (DBIR) (Design-Trial-Evaluation) (see Kirshner & Polman, 2013) to address the research questions (see Table 1). DBIR promotes communication between practitioners and researchers through "agile interventions" as education designs play out in practice (Kirshner & Polman, 2013).

Table 1. Research design

<table>
<tr><th colspan="3">Design Phase</th></tr>
<tr>
<td>Pre-VR immersion learning experience:
• Initial assessment of student understanding and skill development with observation.
• Pre-teaching around targeted Efs concepts and skills.
• Introduction to teachers and students on how to use of VR, including preparation for virtual experiences.
• Observation (video and photos) of class.
• Student survey on experience with VR, understanding of targeted concepts (e.g. marine reserves).</td>
<td>BLAKE NZ-VR educator visit
• Observation (video and photos) of class.</td>
<td>Post-VR learning experience:
• Follow up teaching revisiting and extending target concepts and observation skills.
• Post-assessment of student understanding and skill development of observation as a science capability.
• Observation (video and photos) of class.
• Student survey on understanding of target concepts, VR experience for learning & usefulness of the VR de-sensitising resources.
• Focus group interview questions with selected students on their learning.
• Teacher Interview.</td>
</tr>
<tr><td colspan="3">Evaluation: Refinement of resources and artifacts</td></tr>
</table>

(Note 1: We had originally intended to work with two case study teachers and their classes and to conduct two cycles of DBIR. However, the widespread COVID-19 pandemic in 2020 resulted in the school's closure and the temporary suspension of the NZ-VR programme. The project team was therefore only able to conduct a single cycle of intervention and with a single case study teacher and her class.)

In the research design, there was a pre-VR/introduction to virtual learning experience phase which also included conducting an initial assessment of student understandings of the content area as well as teaching activities to introduce students to targeted EfS concepts and science observation capabilities. This phase was informed by:

1. Several sessions of meeting and planning with the teacher to develop an inquiry unit to allow some initial teaching to occur, incorporate BLAKE's NZ-VR educators' visit and subsequent teaching as a follow up to the visit.
2. Interview with the teacher.
3. Interview with BLAKE's NZ-VR educators.
4. Interview with NZGeo representative who developed the NZ-VR headsets.

Following this introductory phase, BLAKE's NZ-VR educators visited the class and ran their VR-based educational programme introducing students to marine conservation ideas through the NZ-VR headsets. Finally, a follow-up phase of teaching of the targeted EfS concepts and skills, and assessment of student understandings was conducted to extend and assess students' understanding of the ideas introduced and discussed in the earlier phases.

Data collection

Data were collected through the following methods which involved a variety of participants:

1. Interview with the BLAKE NZ-VR educators who conduct the NZ-VR programme to understand their views, rationale, intention/expectation of teachers and students using the VR headsets (see Appendix 3).
2. Interview with the NZ-VR developer (NZ Geographic representative) to understand the rationale (design and/or pedagogical principles) for the design (or affordances) of the NZ-VR experience (see Appendix 3).
3. Interview with the case study teacher, who used our curriculum resource and the NZ-VR headsets to understand how and to what extent the curriculum resources and technology supported student learning (see Appendix 3).
4. Observations (videos and photos) of students' learning to understand how students are interacting with the VR headsets.
5. Pre and post assessment of students' *observation* science capability.
6. Pre and post assessment of students' understanding and learning of targeted EfS concepts and experience with VR (see Appendix 1).
7. Student focus group interview to evaluate their VR-supported learning experiences including the VR desensitising resources (see Appendix 3).

Participants

Participants in the study were:

- BLAKE's two NZ-VR educators
- NZGeo's representative
- The case study teacher and her class of 20 students.
  - 18 students responded to the pre-VR intervention survey (12 females, 6 males).
  - 17 students responded to the post-VR intervention survey (11 females, 6 males)
  - 7 students participated in the focus group interview

The study obtained ethical approval from the Division of Education's Human Ethics Committee, University of Waikato (no. FEDU003/20, approved on 20 January 2020). All participants took part on a voluntary basis.

Data analysis

All interviews were transcribed and participants were given the option of reviewing them. Each dataset was thematically analysed (Braun & Clarke, 2006) to identify key ideas emerging from the study within each participant group (educators, students). Analysis of the video observations were intended to highlight the ways students come to understand *observation* as a key science capability and navigate their virtual learning experiences. Comparisons between student assessment data collected during the introductory and final phases were compared to ascertain the impact in terms of shifts in student understanding of targeted concepts and observation skills. Student survey responses were collated and compared for shifts between the pre- and post-VR intervention surveys (see Appendix 2).

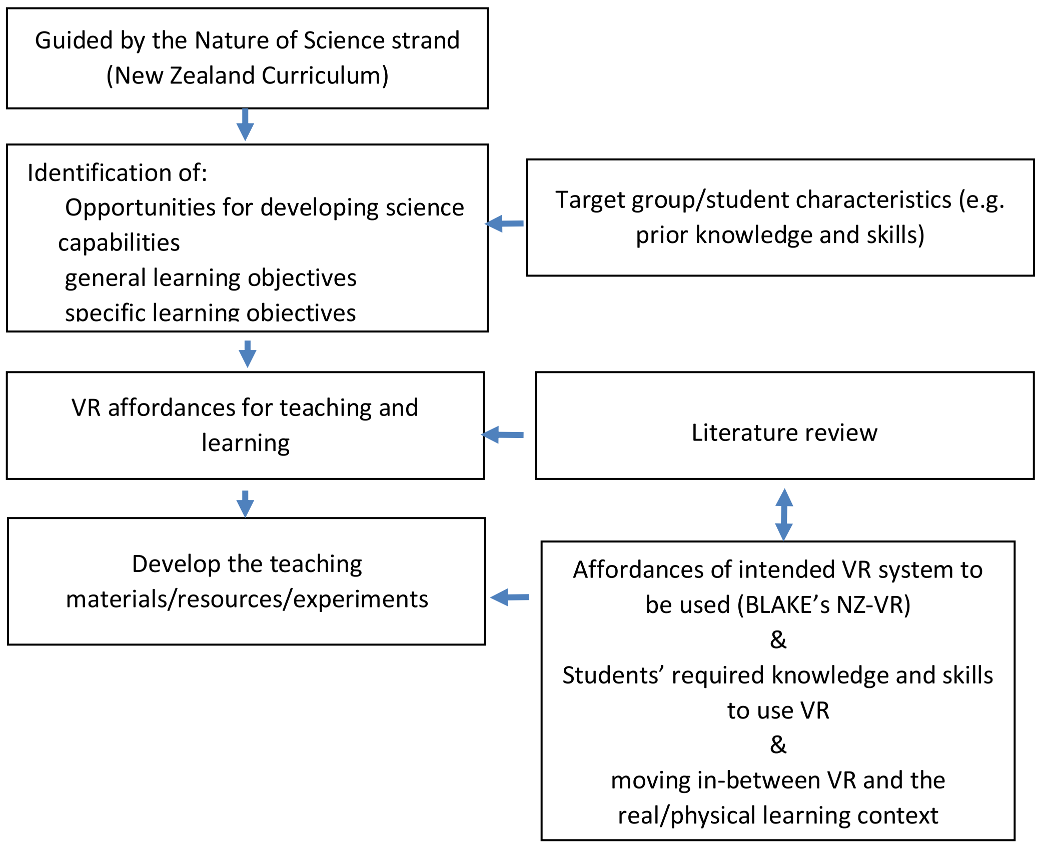
Cross-analysis of the different datasets was then conducted to identify general patterns related to VR-supported teaching-learning experiences. Taken together, the analyses informed the refinement of the curriculum resource. The educational researchers undertook the analysis, interpretation and reporting of the data.

DEVELOPING THE INTERVENTION

We began our development work by developing a working framework that can be used as a guide by educators new to using VR in their practice/with their classes. Several similar frameworks have been proposed to maximise the benefits of using VR in teaching and learning, some of which were based on earlier studies of technology-supported learning (e.g., Connole et al., 2004; Dalgarno & Lee, 2010; Fowler, 2015; Mayes & Fowler, 1999; Olympiou & Zacharia, 2011; Zhou, Ji, Xu, & Wang, 2018).

For the purposes of this study, we have adapted one of these frameworks (see Figure 1).

Figure 1: Framework for developing the curriculum resource artifact to maximize the BLAKE NZ-VR experience for this study.



The framework begins by identifying the curriculum content on which to base the development of resources. We identified the opportunities for developing students' science *observation* capabilities, and general and specific learning objectives. From the general literature, we also ascertained the affordances of virtual learning experiences for teaching and learning. We then analysed the affordances (possible enablers and constraints) of the NZ-VR resources (technology and current teaching materials) and developed relevant curriculum teaching resources to:

- complement the teaching resources currently made available by the NZ-VR programme, and,
- prepare teachers and students for the virtual experience in order to maximize their virtual learning experience while learning the targeted content and skills/capability.

Designing the content resource

A focus on the science capability of Observation

The curriculum resource that we developed focused on the Nature of Science strand with the following details:

> **Strand:** Nature of Science in the NZ Curriculum
>
> **Level:** Primary science curriculum levels 3 and 4

Targeted science capability: The skill of *observation* within *Gather and Interpret Data* capability. The NZ Curriculum describes this particular capability as:

> The Gather and Interpret Data science capability is based on data derived from direct, or indirect, observations of the natural physical world. We gather data by using our senses: sight, hearing, touch, taste, smell–to make observations. Making careful observations often includes measuring something. Observations are influenced by what you already know (Ministry of Education, n.d.).

We explicitly selected *observation* as an area for further exploration in our study. Although the NZ-VR experience lends itself to connections with multiple science capabilities, we considered the skill of *observation* to be a fundamental aspect of science learning which primary students are still developing. *Observation* is a key skill that is transferable across multiple curriculum areas and environments. It is also a key skill needed to further science learning interests and practice. Additionally, as the literature suggests (Balamuralithara & Woods, 2009; Olympiou & Zacharia, 2011), the skill of *observation* can importantly be supported through VR. It is important that students and teachers go **beyond** the notion of observation as a mere physical act of seeing, to involve their other senses (sight, auditory, tactile/movement) including adopting new frames of reference to heighten their observation capabilities.

Our intervention activities gave students opportunities to inquire about:

What is observation? and *Why is it important?* as part of the pre-VR learning phase and revisiting this idea in the later post-VR learning phase.

A focus on learning marine ecoliteracy concepts

We identified that the values encouraged as part of the New Zealand Curriculum (MOE, 2007) that are relevant to the NZ-VR programme for our study were:

- ecological sustainability which includes care for the environment
- innovation, inquiry and curiosity, and,
- thinking creatively, critically and reflectively.

Identified Education for Sustainability (EfS) concepts that can be drawn from to connect with the NZ-VR project for the purposes of our study were:

- Sustainability–the ability of individuals, groups, and communities to meet their needs and aspirations without compromising the ability of future generations to meet theirs, and,
- Interdependence–biodiversity, community, cultural diversity, democracy, globalisation.

We focused on these values and concepts in our planning and development of supporting curriculum resources.

Developing assessment tools to evaluate student learning

In our study, the impact of the study intervention on students' learning was obtained by comparing a baseline measure of students' *observation* capability and initial understanding of the targeted EfS concepts (Sustainability and Interdependence) in the pre-VR learning phase with a second measure obtained in the post-VR learning phase in the intervention. Students were given an initial baseline observation task (see Figure 2) and a similar activity at the end of the study.

Figure 2: Baseline observation assessment task.

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List all the things you see in the photo

In order to assess the extent of students' observation capabilities, we developed a rubric (see Figure 3) based on publicly available rubrics and criteria available through the National Monitoring Study of Student Achievement (NMSSA) Science Capability Scale (SC) (Ministry of Education, 2018) as well as measurement tools from New Zealand Council for Educational Research (NZCER). These identified *observations* to be one of the fundamental skills in science learning and have established measures to evaluate shifts in students' developing *observation* capability.

The assessment rubric consisted of four progressive levels–Levels 1 to 4 denoting "Little/None", "Low", "Moderate", "High". Level 1 reflected a little/no level observational skill consisting of none or minimal basic observations where students used basic terms such as 'fish' or 'bubbles'. On the other hand, Level 4 reflected a high level of observational skill in terms of quality and increase in the number of observations in students' reports indicating a deeper observational capability. Examples included, 'the fish were swimming in the seaweed, possibly to hide', 'lighter and darker kelp', 'disruption on the top of the water', 'different tones of water'.

In addition to identifying student observation capability, the rubric also provided data on targeted marine eco literacy concepts - biodiversity, interactions and ecosystems.

Figure 3: Rubric used for assessment of observational capability and marine ecoliteracy concepts.

Observational skills				
1- Little/none	2- Low	3- Moderate	4- High	**Concepts**
Little number of observations	Students will make a small number of observations Observations will be simple	Students will start to make more detailed observations	Students will make deeper more complex observations. Students will be making some inferences and connections	- Biodiversity - Interactions - Ecosystem

Figure 4: Students completing the pre-assessment of their observation capability.

We also assessed the impact of using VR to support students' understanding of the two targeted EfS concepts by drawing from and adapting from a range of assessment tools available from, for example, the Ministry of Education (2020) and studies conducted by our team members (Eames & Aguayo 2019; Eames, Barker, Wilson-Hill, & Law, 2010). We adapted these to assess for any shifts in student learning and understanding.

Refinements to the developed teaching resources were made after teacher and student feedback/evaluation of their use at the end of the intervention to ensure they were relevant and useful to meeting teaching-learning needs.

Developing the VR-desensitising resources

Previous research had indicated that children with prior VR experiences (VR literate) will be less distracted by the technology and will be more focused on learning the content compared to those for whom the technology is a novelty (Eames & Aguayo, 2019; Southgate et al., 2019). To this end, to minimise the novelty effect of VR use in the class, we facilitated children's learning to use VR-technology including awareness of the social, physical, and ethical issues when using the technology for their learning purposes. We speculated that introducing VR sensitising experiences that are similar to the NZ-VR content to be learned can facilitate children's focusing on the content to enhance learning. To address this issue, we:

1. Developed a resource to educate and inform teachers and students on the use of VR (see Appendix 4 for the refined resource),
2. Introduced a progressive VR desensitising intervention activity to allow students new to the technology to become familiar with the virtual experience. In the pre-VR immersion phase, the class teacher had guided her students to develop their observation capability through firstly, discussing pictures (2-dimensional images) of marine life. As a class they then looked at a few 360 videos from the NZ-VR website where students could control (stop and start for review) their learning experience. Another advantage of the videos was they also included audio. This led to further and more detailed class discussions on marine eco-literacy ideas. This activity was followed by the educational researchers' visit to the classroom to introduce students to using a VR Cardboard headset with mobile phones. We initiated this activity with a class discussion on observation (for example, how our observations are linked to our beliefs/life experiences, followed by an activity on interpreting an ambiguous image, and a discussion on strategies to ensure our observations are robust/accurate). This was followed by a discussion on using VR and going through the guidelines in the resource (Appendix 4). Students were then given guidance for the VR desensitisation activity before being assigned into pairs to work with a buddy partner. Each

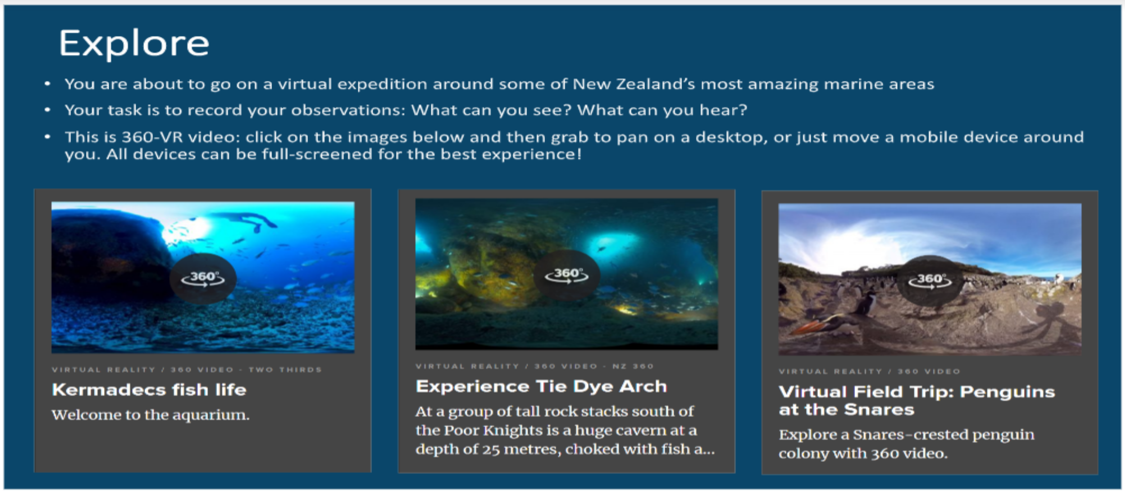
student pair was given a set of Cardboard with pre-loaded 360 videos on a mobile phone which focused on marine life. Students took turns to experience the virtual and immersive learning experience. They had control over the use of the cardboard headset and could move around in pairs as they 'engage' with elements in the video.

The VR-desensitising and supporting resources were later refined after teacher and student feedback/evaluation.

Figure 5: Summary of the progressive VR-immersion experience in the case study class.

	Progressive VR-desensitising experience & quality of immersive experience			
Research Design Phase	Pre-VR learning immersion phase			BLAKE NZ-VR educator visit
Tools used	2-D images	360 videos	VR Cardboard headset	NZ-VR oculus headset
Affordances of tools and student learning experience	• engages students' sense of sight • guidance by class teacher regarding observation properties	• engages students' sense of sight and sound • students have control over their experience - starting and stopping and reviewing guided by the class teacher	• engages students' sense of sight and sound • students have control over their experience - starting and stopping and reviewing • student discussion & expectations on using VR followed by immersion experience with guidance by university researchers • students could move around in pairs as part of 'engaging' with the immersive experience	• engages students' sense of sight and sound • control of students' immersive experience determined and guided by NZ-VR educators • students briefed on using NZ-VR headsets by BLAKE NZ-VR educators • students were seated to experience and engage with the NZ-VR learning experience

Figure 6: A screenshot of the NZ-VR 360 video used in the pre-VR immersion activity.



https://www.nzgeo.com/video/kermadecs-maomao/
https://www.nzgeo.com/video/tie-dye-arch-the-pinnacles/

https://www.nzgeo.com/video/virtual-field-trip-penguins/

Figure 7: Students experiencing the Cardboard desensitisation intervention.

FINDINGS

The findings are reported according to the research questions. Key themes were evident from participants' survey responses and are elaborated through contextualised examples from the teacher and her students' perspectives and quotes.

Research Question 1: What is the impact of using virtual reality to support primary students' understanding of marine eco-literacy?

To contextualise our response to this question, we first explored the teacher's intentions regarding the development of the marine eco-literacy teaching unit, in relation to the students' VR experience. The classroom teacher explained that the virtual learning experience would be part of a novel topic that fitted with a wider school theme on 'Diving into the Deep'. Student learning objectives were focussed in the Living World strand of the New Zealand Curriculum and aimed "to broaden and deepen student understanding beyond animal life for marine conservation", and explore "ecosystem and interconnected systems thinking, including food webs". She hoped her students would develop in-depth engagement with these ideas and have the opportunity to look underwater at elements they would otherwise not be able to see beyond pictures (not many students have been underwater).

The teacher thought this could fit with her teaching intentions for the students to better understand their local and wider environments experienced at annual school camps at Port Waikato and other regional beaches. A key intention was for students to learn to "think and behave like a scientist and to develop awareness of scientific processes as a part of understanding the nature of science".

Evidence gathered from the students through the pre- and post-intervention questionnaires and focus groups suggested that their marine eco-literacy understandings improved after the VR experience, as they demonstrated a greater knowledge (of marine reserves, of overfishing, or marine pollution issues), positive attitudes towards marine environments and expressed intentions to act and had ideas about what to do.

Survey data showed that while some students (10/18) had visited the sea many times a year, nearly half had only been once or twice per year or never to the sea. Of those who had visited the sea, they listed local places within 2 hours drive of their homes, to engage in swimming and surfing. Less than half the students had been snorkeling in the sea. The intervention activity was thus instrumental to their learning about marine life and marine literacy ideas.

Student awareness of marine reserves appeared moderate prior to the VR experience, but the numbers of those believing marine reserves are good for fish rose from 9/17 to 16/17 after the VR experience. Similarly, the number of students who thought we needed more marine reserves rose from 5/18 to 14/17. In the focus group interview, students showed good development of knowledge about the purpose of marine reserves, noting that before the VR experience "I didn't really know what a marine reserve was" but after the experience students offered that "you're not allowed to fish or feed the animals" and "you can't take anything out the marine reserve". Data from the observational tasks pre- and post- the VR experience indicated that students had developed a wider knowledge of biodiversity in the marine environment, including being able to identify different species and use their names.

In addressing the issue of overfishing, when students were asked about their thoughts regarding the statement "I think there are plenty of fish for everyone in the sea", the majority of students (12/17) did not agree at the end of the study.

Prior to the VR experience, 15/18 students already felt that oceans were unhealthy, and this remained almost the same (15/17) afterwards. The VR experience seemed to have some impact, however, as a focus group participant claimed:

> It opened my eyes to see that there's lots of pollution, and it's a huge problem. The marine reserves, you can't throw rubbish in there. And it's like it's colourful–there's coral, there's seaweed, and it's all beautiful and nice. And like the water's clear. And I remember in the virtual reality, yeah, we went to that thing in Auckland, and there were big bits of algae, and algae growing everywhere and there were [old] tyres and there was no fish. There was no seaweed. There was nothing. It was all–it was all polluted.

There was some evidence of development of systems thinking, as one student commented in the focus group, "I also didn't know that what you put in the drain goes out to sea. I thought it just goes underground". This extended into some consideration that humans are a part of these systems, and having an impact, and this appeared to have an emotional effect on the students, as one exclaimed:

> I've learned, and I think a lot of us have learned, is that people just don't care, they just ... Like they just go along, they just throw rubbish everywhere. They don't care that there's this whole ocean that is dying, and that we need. And that there's animals that are going into extinction that are on the endangered list thanks to us. Because **we** are just throwing our rubbish everywhere. And we're just letting all this happen. And we're not trying to make a change, because the ocean is an important part of the world.

This understanding of human impact on biodiversity was also illustrated as a focus group participant related learning about ecosystem changes, saying "like the kina–are taking advantage of what the humans are doing to the ocean". A second focus group student added "if you overfish too much, the fish will go away, and then the kina will come along and eat all the seaweed. So, we have no more fish or seaweed." The exposure to these ideas led to some serious concerns for the students, as one expressed that "in our ocean there's plastic ... plastic. We take the fish out and we eat the fish. Does that mean that we eat the plastic that they ate?"

The survey data indicated that the VR experience had not helped students to develop further knowledge about how to help oceans stay healthy after the intervention, with the proportion agreeing that they knew what to do remaining the same (at 10/17) before and after the intervention. However, in the focus group, in response to the discussion turning to concerns about plastic in the ocean as noted above, the students reported that "we've made our goal, and we're going to make an alternative to plastic", and "we can reuse plastic bags. Even for our lunches we can reuse them instead of just putting them in our lunchboxes, buying plastic bags, using them once and then just throwing them out", while a third student added "or you could get paper bags". This data indicates that the students were thinking about what actions they could take that address the cause of the problem, not just the symptoms, and that they felt some need to exhibit kaitiakitanga for the oceans.

Overall, the key learning outcome from the VR learning experience mainly related to students' engagement in learning about marine reserves with some students expressing an intention for action after the teaching and learning with VR-supported resources.

Figure 8: BLAKE NZ-VR educators sharing knowledge about marine environments.

Research Question 2: What is the impact of using virtual reality to support primary students' learning of the science capability of observation?

The focus of the study had been on students' development of the science capability of observation. For the teacher, this was fundamental to developing other science capabilities. She explained:

> Observation, inference, gathering the data.... Because really there's just observation, they can't measure, they can't... But they can count. They can notice. Just wanting them to know that all scientists begin somewhere, and this is where they all begin. So I really just want them all to be scientists, they can take those skills away with them.

The teacher saw the VR experience and associated learning opportunities as a way to immerse students into a new observational tool that might encourage them to think more deeply. She saw that students could "develop in-depth engagement and have the chance to look underwater at things students can't see otherwise beyond pictures" (not many of her students had previously been underwater). She hoped the VR-supported learning experience would spur students to develop their own action inquiries:

> But after this virtual reality [learning session], hopefully they've [students] got questions they want to delve into. And hopefully they see things that they might not have thought about before. Hopefully they'll just take an interest, because that's when I think I would also try and start exploring what would happen if part of this ecosystem disappeared. If it wasn't there what then? What would happen to the next line? To our ecosystem as it is. So getting them to think a bit further as well.

Over the course of the study intervention, students showed evidence of improved observation skills. By focusing on observation as a specific teaching and learning focus in the VR-based learning experience, students indicated they were able to "pick up more things" and used observation as evidence, that is, the observations they made were more sophisticated. Students were more prepared to consider more deeply what they were seeing. We noted an improved expression of ideas related to biodiversity and interactions between species from the pre- to post-observational task.

Almost all of the students in the pre-VR immersion phase exhibited little or low-level observation skills. However, this appeared to shift in the post-VR task. From the 13 students tracked, nine shifted by two or more levels based on our assessment rubric (Figure 2). For example, from Level 2 to 4 or 1 to 3. Furthermore, four students shifted by one level in their observation capability. for example, from Level 3 to 4 or Level 2 to 3. Overall, there was a positive shift of at least one level for all students, indicating their increasing observation capability. A dedicated focus on developing their observational skills in the pre-VR experience appeared to have some impact. Based on students' feedback in the survey and interviews, they highlighted the teaching and learning about observation as being key in supporting their developing understanding and observation capability.

Identifying that observation involved more than just what students see in the physical world was a focus for the teacher. For example, the sense of sound was identified as an important part of an observation experience and more than half of the students (10/17) felt that having sounds to listen to during the VR experience helped them to feel like they were in the water. They reported the VR experience was a more "real" way to learn than through the internet where fake news can abound. One of the focus group students added how she was more encouraged to take action after the VR learning experience:

> I like researching, but I think that this [VR experience] was better because if you search something up on the internet, it could be fake. You haven't seen it from your own point of view, it's just what people say about it. With the virtual reality, you see it from your own point of view. And then you really understand it much better, and you can pick up more information. It's much better for research, and for understanding... you can see it with your own eyes...More information...and you can tell people what's actually going on, rather than 'fish are dying, we're polluting the ocean'. You can tell them more... Like how we can help.

Additionally, students in the focus group raised the value of the pre-VR immersion experience in preparing them for virtual learning experience and to give them an idea of how to observe in a virtual context:

> The [VR] Cardboard helped because you can actually hear and see what it might look like, rather than just going straight to the real expensive one [with the Oculus headsets]. And you're looking round, and you're like, 'What are we doing? Can I see myself? Can I walk and move forward?'

> Yeah, it just helped...understanding to observe better. Like understanding what it's going to be like to observe what's happen.

Students also raised pragmatic reasons for being able to observe through using VR, as one focus group participant said "because you might not be actually able to go there in real life. But with VR you can go in there and observe the differences between being in a healthy environment", and another added "feel like it's easier, because you're in your *normal* environment. And you're in the water sometimes, it could even be too cold, and you're worried about that".

Being in control in using VR was also highlighted by one focus group participant, saying "With VR you can control where you look. Whereas in a video, it just moves itself and, 'Oh there's something interesting.' With VR you can look straight at it and observe it more".

Overall, the impact of VR-supported learning could be seen in the enhanced depth and quality of student observations at the end of the study. Both the teacher and student awareness of observation involving more than the sense of sight to include the sense of sound was an important step in supporting students' observation capability development.

Figure 9: Students in the BLAKE NZ-VR experience.

Research Question 3: How can the use of VR be purposefully designed into classroom learning experiences?

Our study intervention design included a pre-VR training session including an orientation to observation skills and a VR sensitisation, the VR experience, and a post-VR experience evaluation. While the teacher felt confident in the students' ability to observe she hoped that the VR sensitisation would remove "the wow factor" and better support her students to concentrate on the content.

Through organising the VR visit with BLAKE, the teacher was able to experience the preparation for having the educators visit her class. She indicated that the BLAKE NZ-VR educators' pre-visit information for teachers could be enhanced by going beyond the logistics of their visiting to include teacher endorsements and recommendations of how to embed the VR experience into a teaching programme, and to see how other teachers have used the website resources that accompany the VR experience:

> I'd be looking for recommendations from other teachers. So, I'd be looking for what other teachers think about it. Not just the fact... Yes. So, to register our school roadshow for 2020 here, I would really be looking, 'Well what are other teachers thinking? Is it really worthwhile?' I know it doesn't cost a lot; I don't think. So, I'd be thinking, 'How can I make it work?' I would be wanting other teachers' recommendations, or photos, or just something that showed me how other teachers used it. 'Cause you get lots... Teachers get bombarded with lots of these different roadshows. And you want to know it's worthwhile.

The teacher stated that such information would reassure her that the BLAKE programme would have value beyond the type of one-off experience that some providers offer:

> Yes, well if it was just a once off [experience], I wouldn't connect. So, I'd only connect if I'm connecting it to my learning. So, for me... this email, if this goes out to schools... It just tells me what I can do, and links me into there. It doesn't give me a lot of information about this side of it. I would really want to know that it's worthwhile, that the kids are going to get something out of it. It's actually going to engage them in learning, and it's actually going to enhance their learning. And it's not just going to be a one-off experience ... that they just ditch that and go somewhere else. So, for me it's got to be usable.

During the VR desensitisation process, students provided valuable feedback on the guidelines (see Appendix 4) and affirmed the value of the process to help them prepare for an immersive learning experience. The guidelines highlighted that some people can experience feeling dizzy after taking their headsets off, especially if they have been very actively looking around, and one student in the study reported feeling like this. The guidelines advise students to be seated during the experience, and in this case the students were. One focus group student said "I think the [desensitising activity] helped because you can actually hear and see what it might look like, rather than just going straight to [using] the real expensive one [Oculus headsets]. And you're looking round, and you're like, 'What are we doing? Can I see myself? Can I walk and move forward'?". Another student added that she thought the process helped her in "understanding to observe better. Like understanding what it's going to be like to observe what's happening".

As noted above, there was some evidence that an inclusion of a pre-VR focus on developing observation skills may have impacted students' ability to observe more effectively during the VR experience, with respect to both sight and sound.

Prior to the delivery of the VR experience in the study class, the BLAKE educators were interested to know how it would be received at an inland school, as previously their work had been with schools close to the coast. One outcome from participating in the study was a realisation that videos of local waterways are important to increase relevance for the students. This approach, they thought, combined with attention to use of appropriate language and terms, and location photos, for the local area, was effective and is subsequently being trialled in other regions.

When asked about the affordances of using VR to teach and learn in the unit, students clearly enjoyed using VR to learn about marine environments. Eleven students (11/17) affirmed this. One student summed up the experience as "1. The feeling that I was actually there. 2. Realising what's happening to the ocean and how we can fix it", while another added thoughtfully "I thought it was interesting to see what we're doing to our oceans, but I must say I'm really surprised at how much damage was actually causing to our oceans". In the focus group, students added they "wanted more opportunities" to learn through VR.

Students were very positive overall about the incorporation of a VR experience in their learning. Most (12/17) felt that VR-supported learning experience helped them learn better than a usual classroom lesson. They attributed this to the experiential and fun nature of learning which facilitated their understanding:

- Visualisation and experiential nature of learning through VR
  - because we got to see what it was like and VR helped us to see what the whole purpose is of marine reserves and how we can save them,
  - it was better than watching a documentary and VR made you see more and learn more,
  - if it was a usual class lesson you would just get told this and that about the ocean but with VR you actually get to see for yourself,
  - because you can see what you are looking at better with VR, you can move around,
  - we could see clearly, look at what we are seeing and that you have your own VR headset.
- Fun
  - because it was something new to learn about and that it was fun,
  - just a change in how we are learning.
- Ease of understanding

- because it is easier to understand,
- you get to learn about fish and the marine.

The students enjoyed the experience so much that they found the educators talk in-between the VR video excerpts less appealing.

When asked if they had advice for students using VR to learn in the future, one commented “do not stand up, listen to every noise around you in the water” and another added “to concentrate on what's happening and to look and listen carefully”.

In reflecting on the outcomes of their own experiences, the BLAKE educators noted that they felt a limitation of the programme was the short-term duration of their interaction with teachers and their students. They wondered about the impact of providing resources as they had no control over how or whether these get used. They would like to expand the programme to increase contact duration and spread, including beyond a single teacher at a school, but noted that this is dependent on funding.

The teacher was clear that the BLAKE NZ-VR experience should not be seen as an add-on, but as a complementary part of a teacher’s planning. Further development of post-VR experience resources to deepen and extend student learning would help. In response, the BLAKE educators have developed a new post-visit resource with follow up questions for teachers and students.

RECOMMENDATIONS

This study investigated the impact of virtual reality-supported teaching on primary student learning of marine eco-literacy and the science capability of observation. The findings affirmed that VR can be a valuable learning tool to offer students learning opportunities they would otherwise not have access to (Olympiou & Zacharia, 2012; Huang et al., 2016; Shin, 2017) and to allow students to interact with complex scenarios /artifacts/situations to develop and practice real-world skills in a safe environment (Balamuralithara & Woods, 2009). Our findings suggest that the study intervention enhanced student learning of marine-ecoliteracy ideas and added to their sense of urgency to act. Student observation skills were enhanced.

Recommendations from the study are as follows.

Enhancing the VR resource:

- Evaluate the extent to which the NZ-VR programme fosters authentic, experiential, inquiry-based and game-like learning. Other scholars have pointed to these characteristics needed for highly engaging and effective VR-supported learning experiences and VR-supported learning experiences should also include and foster social interaction.
  - To design for engaged learning, Iqbal et al. (2010) claim that virtual environments should be– authentic, experiential, inquiry-based, game-like - and they should be designed to foster social interaction. Although teachers may not simultaneously engage students in all four dimensions at once, the design of the virtual learning experiences ought to aim for an interplay of multiple dimensions of engagement.
  - Other scholars such as Aguayo et al. (2018) draw attention to the idea of ‘embodiment in VR’ as a way to increase the authenticity, engagement and immersiveness of the VR-supported learning experience. This involves engaging students’ whole body and senses while using VR/AR (augmented reality)/XR (mixed reality). For example, to promote students’ awareness and ‘use’ of their bodies while experiencing the underwater world in VR mode educators could invite them to swing their arms while laying on their tummy. They could complement students’ VR experience with haptic and sensorial experiences by using different materials and artefacts (involving aesthetical response) to simulate the ‘touching of underwater things’ to increase authentic learning.

Working with schools and teachers:

- Reconsider the value of visiting many schools for short periods
  - Immersive whole day inquiries can lead to deeper long-term impact and deeper learning experience.
  - Consider an outreach model that can embed/incorporate inquiry-based teaching-learning philosophies and beliefs.
- Review scheduling procedures and prior-visit support
  - Reconsider the value of visiting many schools for short periods as opposed to fewer schools for longer periods
  - Revise and enhance outreach email to include teacher recommendations and exemplary VR-based teaching practice ideas.
- Revisit teacher professional learning provision to provide greater support for teachers to explore and employ ways to contextualise learning around the VR resources and the BLAKE educator visit
  - Consider building in options for a hands-on professional development (PD) session for teachers by, for example offering an immersive inquiry workshop with teachers for a day using the VR headsets and or by working with a Professional Learning and Development provider (PLD).

- VR de-sensitisation is important for teachers and students

- Include teachers and students in the trialling of a pre-VR experience trailer to help reduce the 'wow factor'.
- Monitor and consider the balance of self-directed and directed learning in VR de-sensitisation.
- Alert teachers to the need to encourage students to focus on their observation capability development and other content-appropriate learning.

- Introduce VR guidelines for teachers and students to maximise learning from VR use. The refined guidelines from our study offer a common language to clarify, explain and support VR-based teaching-learning practice.
- Encourage teachers to plan for VR to be part of a digital continuum inquiry approach.
  - The teaching inquiry can be integrated with a digital immersion approach. This could include developing an inquiry through progressive immersive experiences ranging from using printed and/or online resources to including AR (augmented reality), VR, or MR (mixed reality), or even integrating VR with other learning affordances such as colouring sheets, board games, web-based resources, videos, or interactive games, as well as with other non-digital learning resources where appropriate (see Aguayo, Eames & Cochrane, 2020). Such an extended reality (XR) approach (incorporating real and/or virtual environments and human-machine interactions generated by computer technology and wearables) can offer students different sources of vicarious learning experiences to not only better understand abstract ideas and concepts, but also to better suit the range of possible individual learning needs. Educators will however need to be upskilled to be able to consider and incorporate this in their teaching.
- Encourage teachers to plan for follow-up from the VR experience.

BLAKE educator learning and development:

- Consider some further professional learning and development for BLAKE NZ-VR educators who already have the content knowledge but might benefit from developing further pedagogical strategies for working with students:
  - Possible foci might be how to enhance the delivery of the content knowledge through pedagogical strategies such as questioning, group discussion, student reflection.
  - Scholars such as Sharples (2019) recommend that teachers and designers of immersive educational technology understand how learners enter a flow state of learning (see Csikszentmihalyi's flow theory, 1996). He offers the following in relation to how flow can be prompted and maintained and how it can contribute to effective learning:

    > ... restrict each session of immersion activity to 15 or 20 minutes, followed by a time to reflect, take notes on the experience, think about what worked and what could be improved and set a goal for the next session. … What's important is that pedagogy is designed around a rhythm of engagement and reflection with each immersive experience extending the skill, offering active engagements and providing material for reflection and discussion. (Sharples, 2019, p.183–184)

- Explore partnering with a PLD provider to support schools and teachers to maximise BLAKE's NZ-VR pre- and post- visits.

Promoting the VR resource as a NZ-VR resource:

- Explore a variety of avenues for alerting teachers and schools to the resource.
- Consider supporting teachers to share their experiences as part of promoting BLAKE's VR resource as distinctively NZ based.
- Consider linking to the Science Learning Hub as one avenue to disseminate successful teacher stories as exemplars of effective VR-based teaching and learning practice to science educators.

LIMITATIONS OF THE STUDY

Two key limitations of this study are:

- It is a small qualitative case study conducted in a primary classroom context with a limited number of participants. The generalisability of the study's findings to other educational contexts is therefore limited, and,
- The research team has limited control of the participants' background and the extent participants offer truthful responses.

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Appendix 1. Pre-and post-VR intervention surveys of student understanding and learning of targeted marine eco-literacy concepts and experience with VR

Pre-VR Intervention Survey

1. Please tell us your name:________________
2. What is your gender: M / F
3. Have you been to the sea with your family?
   - Never
   - 1-2 times per year
   - Many times a year
   - Others
4. If you go to the sea, where do you go the most: __________________
5. Have you visited any marine reserves? Y/ N
6. If you answered 'Yes' above, please tell us which marine reserve you have been to: _______
7. I think marine reserves are good for fish.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
8. I think we have enough marine reserves and don't need any more.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
9. I think there are plenty of fish for everyone in the sea.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
10. Have you ever been snorkeling and seen under the water? Y/ N
11. I think the ocean is clean/healthy and not polluted.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
12. I know what to do to help the oceans stay healthy.

- Strongly agree
- Agree
- Not sure
- Disagree
- Strongly disagree

13. Have you looked at a 360 video before? Y/ N / Not sure
14. Have you heard of VR or virtual reality? Y/N / Not sure
15. Have you used or had any experience with using VR? Y/ N / Not sure
16. If you answered 'Yes' to the previous question, how many times have you used VR?
    - 1-2 times
    - 3-4 times
    - More than 5 times
17. If you have experience using VR, please tick which picture or pictures below best show how you have used /accessed VR.

A. 

B. 

C. 

18. I would rather go snorkeling to see fish in real life than watch them on VR.
    - Strongly agree
    - Agree
    - Not sure
    - Disagree
    - Strongly disagree

Thank you for your time.

Post-VR Intervention Survey

1. Please tell us your name:______________
2. What is your gender: M / F?
3. I think marine reserves are good for fish.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
4. I think we have enough marine reserves and don't need any more.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
5. I think there are plenty of fish for everyone in the sea.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
6. I think the ocean is clean/healthy and not polluted.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
7. I know what to do to help the oceans stay healthy.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree
8. I would rather go snorkeling to see fish in real life than watch them on VR.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree

9. I liked/enjoyed using VR to learn about marine conservation in my class.

- Strongly agree
- Agree
- Not sure
- Disagree
- Strongly disagree

10. Please tell us why: ________________
11. Using VR helped me learn better than if it were a usual class lesson.
    - Strongly agree
    - Agree
    - Not sure
    - Disagree
    - Strongly disagree
12. Please tell us why: ________________
13. The underwater sounds in the VR experience helped me to really feel like I was in the water.
    - Strongly agree
    - Agree
    - Not sure
    - Disagree
    - Strongly disagree
14. What two things did you like the MOST about learning through using VR in this topic? _____
15. What did you like the LEAST about learning through using VR in this topic? __________
16. If it were up to you, what ADVICE would you give to a teacher about learning through VR?

    ____

Thank you for your time.

Appendix 2. Student responses in the pre- and post-VR intervention surveys

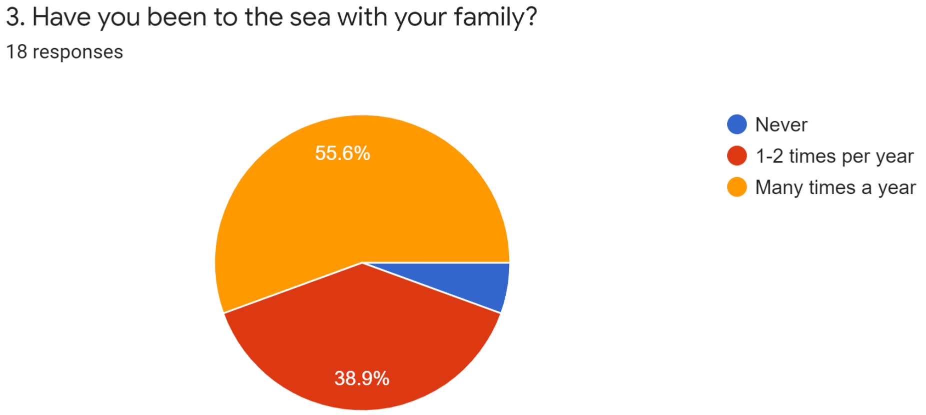
The number of participants in the pre-intervention survey were 18 students: 12 females and six males.

The number of participants in the post-intervention survey were 17 students: 11 were female while six were male students.

Pre-Intervention Survey Responses

Note: comparisons have been made between responses to six questions that were asked in both the pre and post surveys

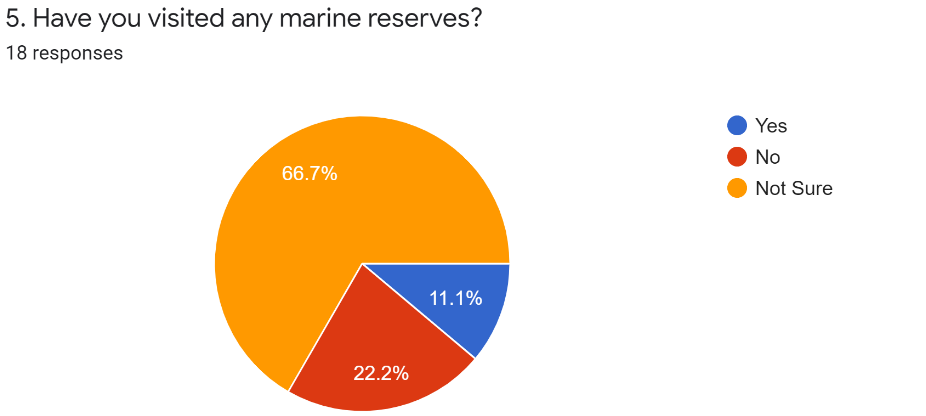
Question: Have you been to the sea with your family?



The majority of students (10 students) have visited the sea many times with their family while seven students have visited the sea 1 to 2 times and one student has never visited the sea.

Question: If you go to the sea, where do you go the most?

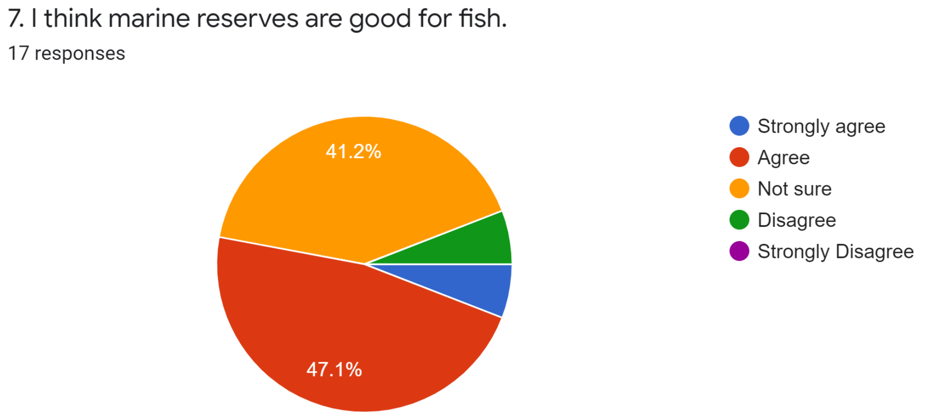
For this question, 17 students either cited the names of beaches they have visited or the kinds of activities they have participated in. Examples of beaches: Papamoa Beach, Raglan, the Mount/Tauranga (5), Pauinui beach, Ngarunui beach, Rotorua beach, Matarangi. Activities reported included surfing, swimming.



Twelve students were Not Sure if they had visited a marine reserve indicating they were uncertain what a marine reserve was, four students had not visited any marine reserves while two students had.

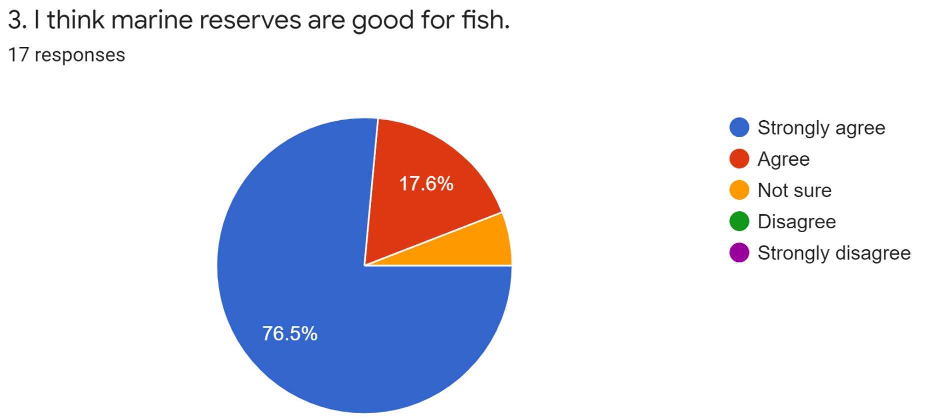
When asked which marine reserve they visited, two students indicated the ones they had visited were in Fiji.

Question: Comparing between responses for the pre vs post intervention survey to the question "I think marine reserves are good for fish"



Pre- intervention: When asked if they thought marine reserves were good for fishes, eight students Agreed, seven were Not Sure, while one student Strongly Agreed and one student Disagreed with this statement respectively.

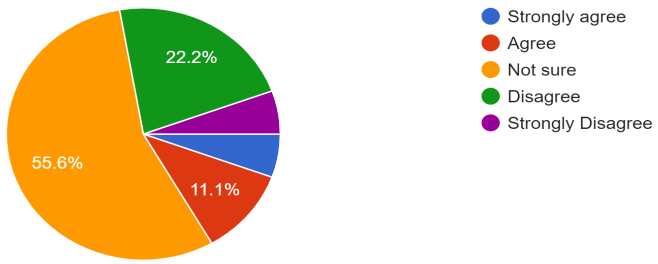
Post- intervention responses:



When asked if they thought "marine reserves were good for fish", a majority of students (13 students) responded that they Strongly Agree, three students Agree while one student was Not Sure.

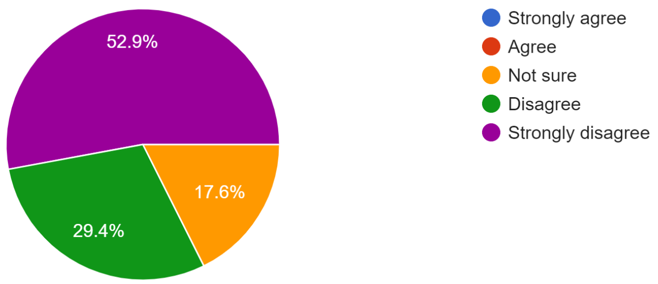
Question: Comparing between pre vs post intervention responses to the question, “I think we have enough marine reserves and don't need any more.”

8. I think we have enough marine reserves and don't need any more.
18 responses



Pre- intervention: In responding to the statement “I think we have enough marine reserves and don’t need any more”, 10 students indicated that they were Not Sure about this statement, four students Disagreed, two students Agreed, one student Strongly Agreed another one student Strongly Disagreed.

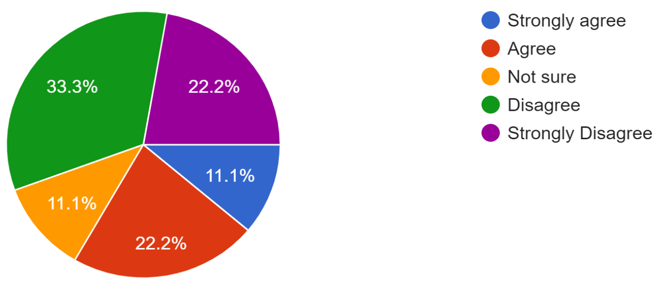
4. I think we have enough marine reserves and don't need any more.
17 responses



Post-intervention: When asked to respond to the statement, “I think we have enough marine reserves and don't need any more”, nine students Strongly Disagree, five students Disagree while three students were Not Sure.

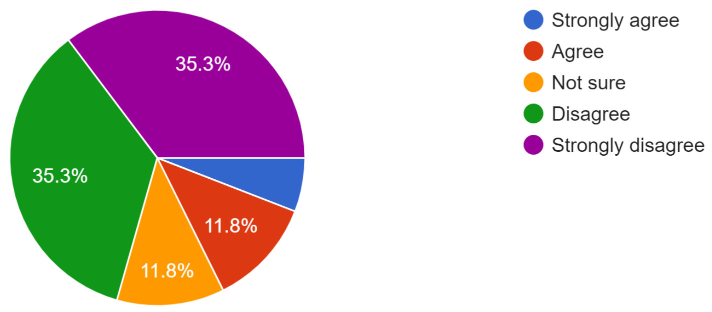
Question: Comparing students responses between the pre-intervention to post-intervention responses to the statement “I think there are plenty of fish for everyone in the sea.”

9. I think there are plenty of fish for everyone in the sea.
18 responses



Pre-intervention: When asked for their response to the statement “I think there are plenty of fish for everyone in the sea”, the majority of students (10 students) combining Disagree and Strongly Disagree disagreed with this statement, another four students Agree, while two other students chose Strongly Agree and another two more students were Not Sure.

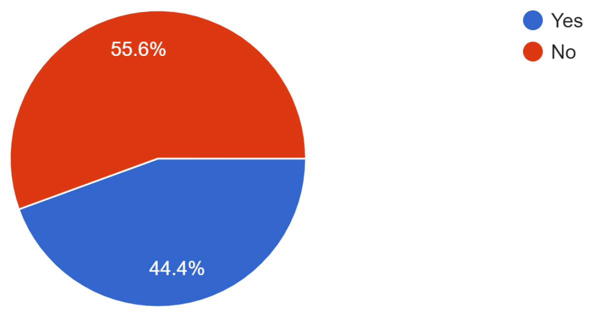
5. I think there are plenty of fish for everyone in the sea.
17 responses



Post- intervention: In asking students about their thoughts regarding the statement “I think there are plenty of fish for everyone in the sea”, the majority of students (12 students combining Strongly Disagree and Disagree) did not agree while two students were not sure. Another two students Agree to this statement while one student Strongly Agree with this statement.

Question: Have you ever been snorkeling and seen under water?

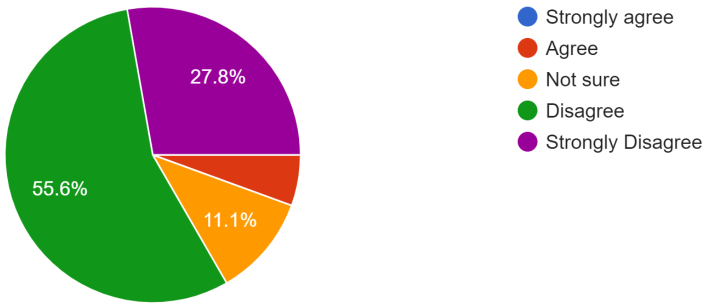
10. Have you ever been snorkelling and seen under the water?
18 responses



When asked if they have experienced snorkeling and seen under the water, 10 students replied No while eight students answered Yes.

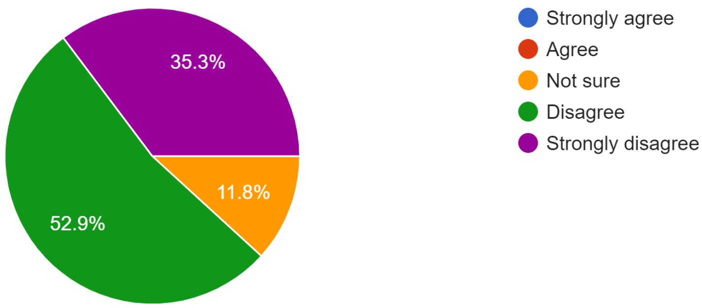
Question: Comparing students' pre-intervention vs post-intervention responses to the question, "I think the ocean is clean/healthy and not polluted."

11. I think the ocean is clean/healthy and not polluted.
18 responses



Pre-intervention: When asked for their opinion regarding the statement "I think the ocean is clean/healthy and not polluted", 10 students Disagree, five Strongly Disagree, two were Not Sure and one student Agree.

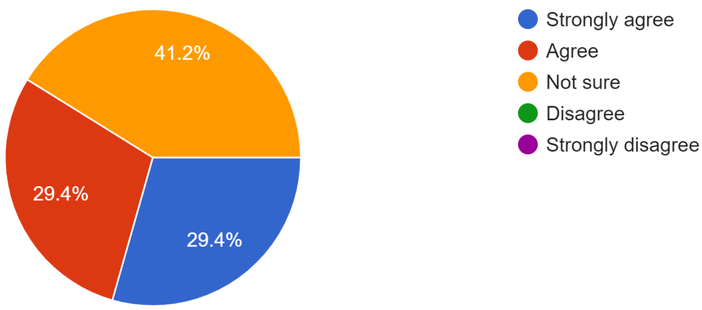
6. I think the ocean is clean/healthy and not polluted.
17 responses



Post-intervention: When asked if they thought "the ocean is clean/healthy and not polluted", the majority of students (15 students combining Strongly Disagree and Disagree responses) disagreed while another two students were Not Sure.

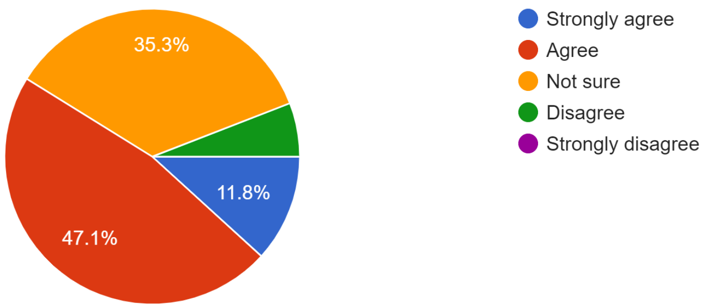
Question: Comparing students' pre vs post-intervention responses to the statement, "I know what to do to help the oceans stay healthy."

12. I know what to do to help the oceans stay healthy.
17 responses



Pre-intervention: When asked for their responses to the statement "I know what to do to help the oceans stay healthy", 10 students Agreed (combining Agree and Strongly Agree), while seven students were Unsure.

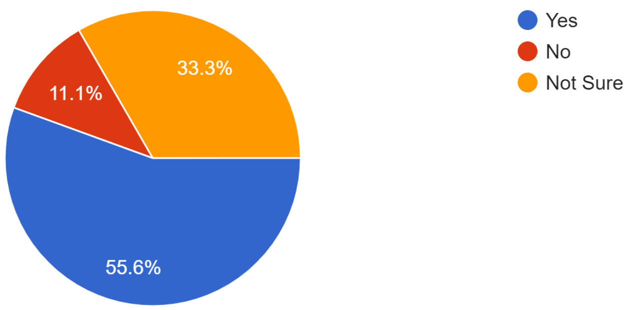
7. I know what to do to help the oceans stay healthy.
17 responses



Post-intervention: The majority of students (8 students) agreed that they knew "what to do to help the oceans stay healthy", while six students were Not Sure. Two students 'Strongly Agree' with this statement while one student Disagrees.

Question: Have you looked at 360 video before?

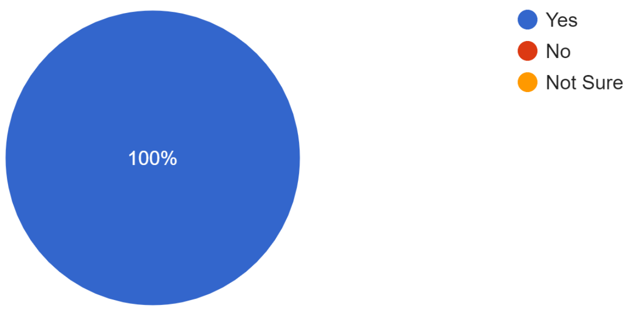
13. Have you looked at a 360 video before?
18 responses



When asked if they had looked at a 360 video before, the majority of students affirmed they had (10 students), while six were Not Sure and another two students indicated they had not.

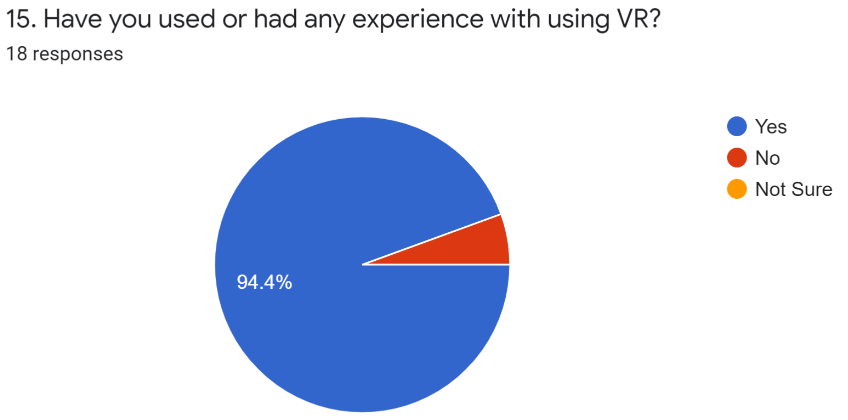
Question: Have you heard of VR or virtual reality?

14. Have you heard of VR or virtual reality?
18 responses



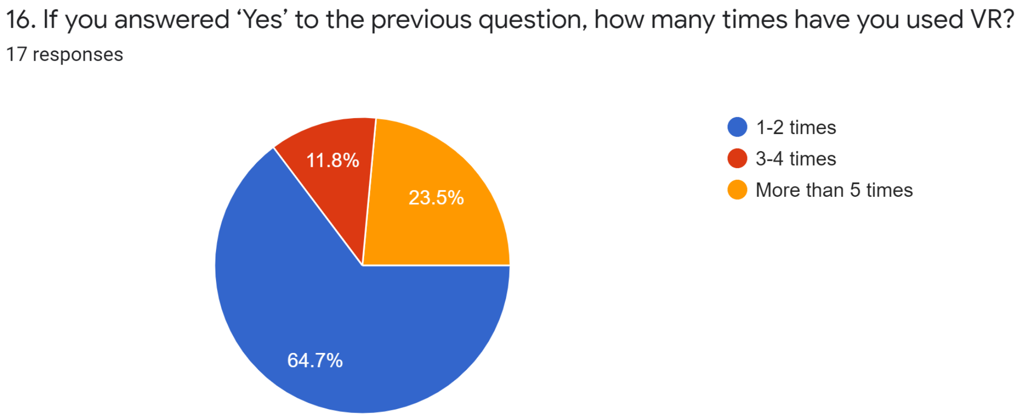
When asked if they had heard of Virtual reality (VR), all students affirmed they had.

Question: Have you used or had any experience with using VR?



When asked if they had used or had any experience with using VR, the majority of students had (17 students) while one had not.

Question: If you answered 'yes' to the previous question, how many times have you used VR?



Of those who indicated they had used/experienced VR before, a majority of students had used it at least 1–2 times (11 students), while four students had used it more than five times, and another two students had used between 3-4 times.

Question: Students were given three options of possible ways they have used/accessed VR.

Below were their responses.

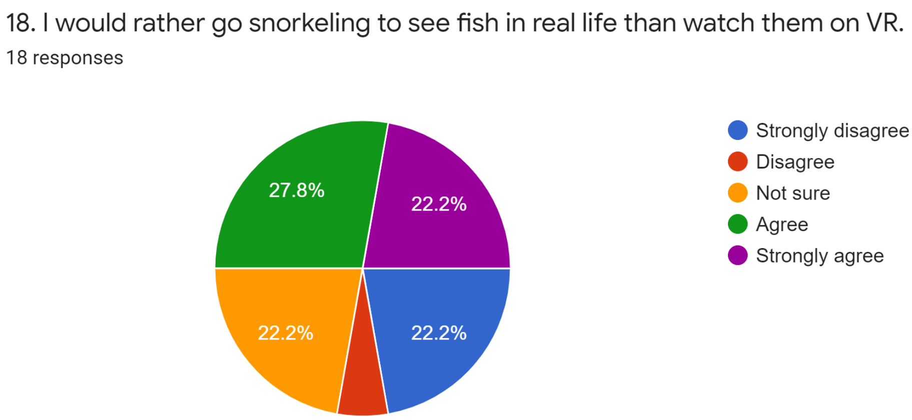

This option was selected by nine students

This option was selected by seven students

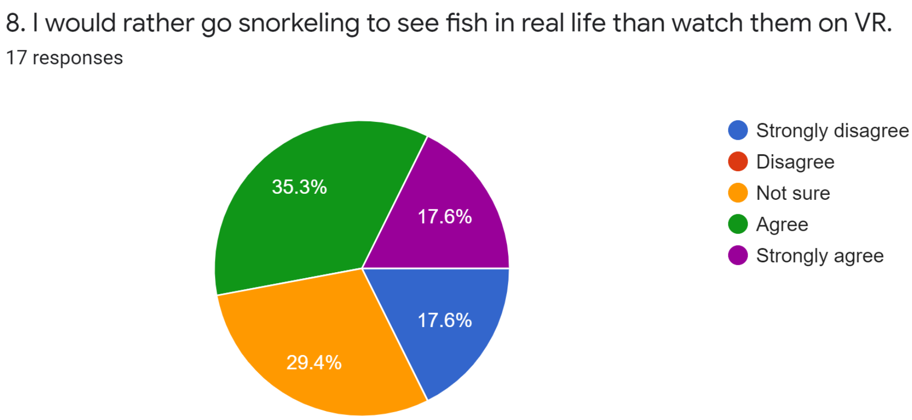
 This option was selected by three students.

Other options mentioned by students included “PS4 VR” and experiencing VR while “sitting in a moving chair with the headset on”

Question: Comparing between students’ pre vs post-intervention responses to the statement,” I would rather go snorkeling to see fish in real life than watch them on VR.”



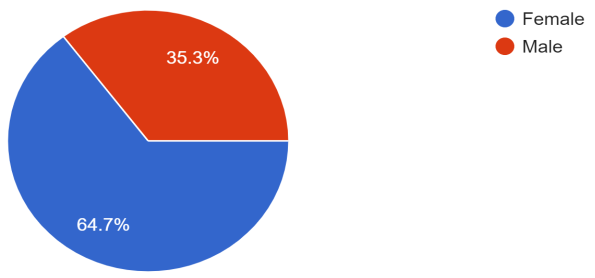
Pre-intervention: When asked to respond to the statement “I would rather go snorkeling to see fish in real life than watch them on VR” students, five students Agreed while the rest were equally divided with four students respectively Strongly Agree, four students Not Sure and another four students Strongly Disagree. Only one student Disagreed to this.



Post-intervention: When asked if they “would rather go snorkeling to see fish in real life than watch them on VR”, students were fairly split in their responses: six students Agree, five students were Not Sure, while students were equally divided in their Strongly Agree (three students) and Strongly Disagree (three students) responses.

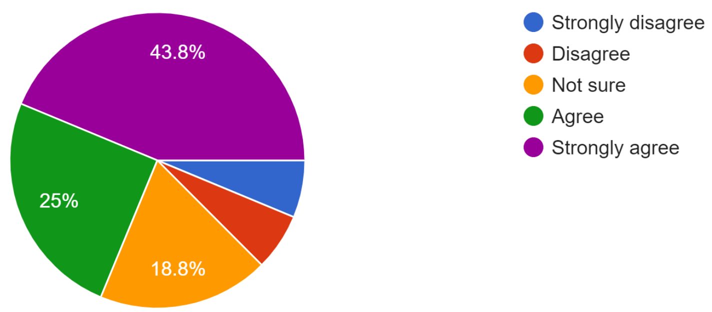
Post-Intervention Survey Responses

2. What is your gender?
17 responses



Question: I liked/enjoyed using VR to learn about marine conservation

9. I liked/enjoyed using VR to learn about marine conservation in my class.
16 responses



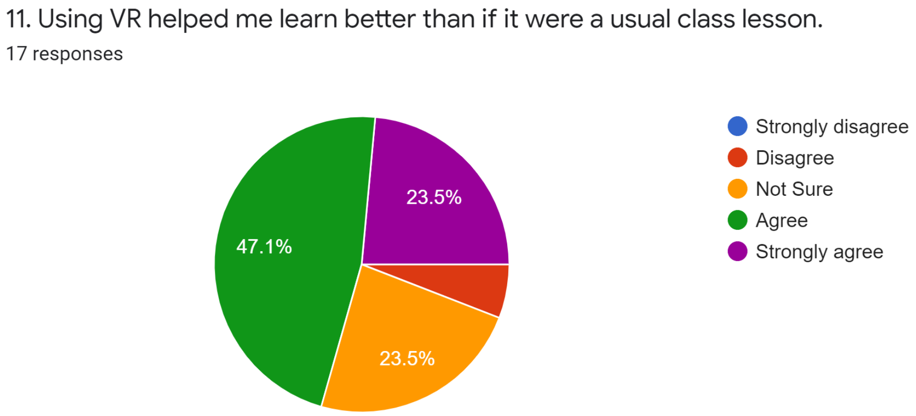
In responding to the statement "I liked/enjoyed using VR to learn about marine conservation in my class", the majority of students (11 students) combining Strongly Agree and Agree responses concurred, three students were Not Sure while one student Disagree and another Strongly Disagreed to this statement.

When asked for their reasons for liking/enjoying using VR to learn about marine conservation, students' responses can be thematised into the following:

Gaining knowledge	• It help me know more about marine reserve. • Because it was a fun and realistic experience it helped me to get a better picture of what the marine reserves were actually about and gave me a better understanding. • Because it helped me learn more about marine life and marine pollution. • It helped me understand what is going on in the oceans and that we need to do something about it. • Because it told us what we need to do to help our oceans. • because i have to talk to people. • the talking ladies and stopping the VR.

Realism/bringing to life	• because it felt like it was real. • you got a great opportunity to look deeper and it really does just show how polluted our oceans are! • You can see what is in the sea without actually going to that place in real life. • It was a great experience.
Fun	• Because it is a fun way of learning. • It's a fun way of learning. • It was fun learning marine in my class.

Question: Using VR helped me learn better than if it were a usual class lesson



When asked if using VR helped them learn better than in a usual class lesson, the majority of students (12 students) combining Strongly Agree and Agree responses affirmed it did. Four students were Not Sure while one student Disagreed.

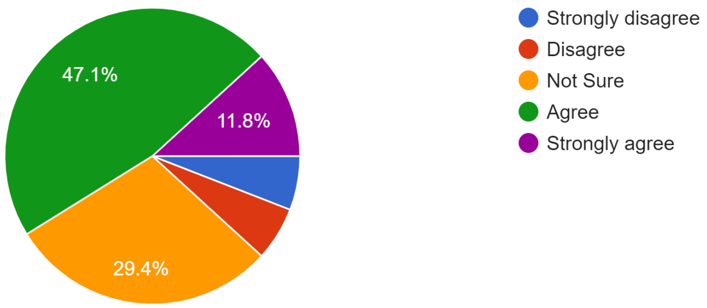
When asked for reasons why they thought VR helped them learn better compared to in a usual class lesson, student responses fell mainly in the following themes:

Visualisation and experiential	• Because we got to see what it was like and the vr helped us to see what the whole purpose is of marine reserves and how we can save them. • It was better than watching a documentary and doing vr made you see more and learn more. • I find seeing better to use than hearing. • If it was a usually class lesson you would just get told this and that about the ocean but with VR you actually get to see for yourself. • Because it showed us what is happening to our ocean. • Because you can see what you are looking at better with VR, you can move around.

Novelty and fun	• Because it was something new to learn about and that it was fun.

	• Just a change in how we are learning. • It was soo much fun!!!
Ease of understanding	• Because it is easier to understand. • You get to learn about fish and the marine.

13. The underwater sounds in the VR experience helped me to really feel like I was in the water.
17 responses



When asked if they thought the "underwater sounds in the VR experience helped me to really feel like I was in the water", the majority of students (10 students) combining Strongly Agree and Agree responses affirmed it did. Five students were Not Sure while two students combining Disagree and Strongly Disagree responses did not agree with this statement.

Students' responses to the two key things they liked MOST about learning through VR about the topic revolved mainly around:

Visualisation and experiential nature of VR	• I can look at fish and see the sea. • Looking at fishes with VR. And moving around to see the fishes and their habitats. • Fish swimming through the water. • It was very fun and realistic and helped us to get a good picture of the underwater. • Seeing the difference of healthy and unhealthy and seeing the underwater sea. 1. The feeling that I was actually there. 2. Realising what's happening to the ocean and how we can fix it. • I thought it was interesting to see what we're doing to our oceans, but I must say I'm really surprised at how much damage was actually causing to our oceans. • We were shown what is happening to our ocean and what is happening to the ocean if we take out all the fish, shells ,seaweed and kina. • That we could see clearly look at what we are seeing and that you have your own VR headset. • I liked seeing how polluted the ocean was and how we could help. I liked seeing the fish and stingrays. • Getting to see the different fish.

Learning about the topic	● Marine life and marine reserves. ● Marine animals and marine pollution. ● The Whales and the story of the man getting killed by a stingray. ● Using the VR and learning about the marine reserves.
Novelty and fun	● It was fun and easier to cooperate with. ● it was very fun and realistic and helped us to get a good picture of the underwater

When asked what they liked LEAST about learning through using VR in this topic, student responses can be categorised into the following:

Learning about the topic	● Fish ● Seeing how grouse our ocean is. ● some time it was ever bad down there
Boring bits	● All the talking. Sorry it was kinda boring. ● "How quickly the videos ended. ● Taking off the head set. ● The part when the lady had to talk and stop the VR ● everyone gets excited about nothing

When asked what ADVICE they would give to a teacher about learning through VR, students' replies included:

Advice related to VR use	● Look carefully. ● Turn off the lights. ● Do not stand up, listen to every noise around you in the water . ● It is much easier than looking at a picture because you can see all around you. ● Not to have cardboard VRs in the first place.
Advice related to learning about the topic	● Use your senses. ● That you can see what you are looking at very clearly. ● To concentrate on what's happening and to look and listen carefully.

More use of VR or similar tools for learning	● Do it more. ● Do it more often. ● We should use it more or something similar

	• It’s fun and it means you're not using the same way of learning every day you're doing something to show us how to learn in a fun and creative way. • Nothing, it was sooo! much fun I had a great time, thank you so much!!!

Appendix 3. Interview questions for NZ GEO, BLAKE NZ-VR educators, teacher and students

Interview questions for NZGeographic representative and BLAKE NZ-VR educators

1. Tell us about the goals of the NZ-VR programme? What was the purpose for running the programme? Why VR—Why not another type of immersive platform/affordances or delivery medium? What do you see are the benefits of using VR to support teaching and learning in the classroom?
2. How did you come to be part of the programme?
3. How did you put together the concept/design for the programme?
4. What was the rationale for running the programme in its current form (e.g. planning, choice of resources used, scheduling around schools, choice of staff, time allocated for the programme etc)? What are the key ideas/skills/learning you wanted participants in the programme to take away from this experience?
5. What did you do in the programme to promote these skills/key areas of learning? [Check role undertaken, types of activities, resources used, support from other staff etc.]
6. How did it fit with your thinking about effective ways to support participants' learning and developing understanding and skills about marine conservation?
7. Did you notice any benefits to participants' learning and development as a result of the programme? [Please explain.]
8. Did you have any concerns/ face any challenges with the running of the programme? [Based on your experience.]
9. How would you change things? [Types of activities, planning, resources, timing, etc.]
10. Can you suggest ways the programme might be extended to cater to participants' / other community users' learning needs?
11. Are you considering 'updating' from VR to another type of platform delivery? And if yes, why?
12. Is there anything else you'd like to share?

Interview questions for case study teacher

Pre-intervention:

1. How long have you been teaching at this school? How long have you been teaching this level of students?
2. What is your purpose for teaching this topic about marine conservation? How do you see it fitting with the NZ Curriculum? What are the learning outcomes that you envisage from this topic?
3. How do you see the role of using VR in supporting student learning of this topic? What are your expectations of what will happen? What are the key ideas/skills/learning you'd like your students to take away from this experience?
4. How are you planning the teaching of the unit to maximise the use of VR based resources?
5. Do you have any concerns about the teaching and learning of this topic/using VR/working with BLAKE?
6. How can you address them/mitigate any issues during the teaching of the topic?
7. Is there anything else you'd like to share?

Post-intervention:

1. How did you think the teaching of this topic went in terms of student learning of marine conservation ideas?
   - What seemed to work well and what not so well? Why do you think that was?
2. How did you think student learning to develop their observation capability went in this topic? [Probe: use of preparatory activities e.g., sensitising, VR headsets and post-intervention activities.]
   - What seemed to work well and what not so well? Why do you think that was?
3. How engaged did you feel the students were in their learning of marine conservation and observation capability compared to if there was no study intervention?
4. What sort of changes in student attitudes, actions, did you notice (if any)? Can you give us some examples/highlights?
5. How did the order of events (pre, VR and post intervention) work for you and the students?
6. What do you think about the use of VR-supported learning opportunities in this topic?
7. Which aspects of the study intervention did you think were most useful to your teaching? To student learning?
8. How did it fit with your thinking about effective ways for students to learn?
9. What learning outcomes do you feel were achieved?
10. Did you have any concerns/challenges with implementing this topic? What would you improve for next time? How would you change things?
11. Based on your experience, how can the use of VR in the classroom be improved for other teachers?
12. Is there anything else you'd like to share?

Interview questions students (focus group interview)

1. Please share with us what you did in this topic.
2. Please share with us what you learnt about marine conservation in this topic?
3. What have you learnt how to do in this topic? (what sort of skills you think you have developed as a result of the teaching of this unit.) [Probe: learning to develop observation skills, marine conservation actions.]
4. What was the best part about learning in this topic? Can you share with us some examples/highlights?
5. What was the best part about learning using VR? Can you share with us some examples/highlights?
6. Would you have preferred to learn about marine conservation through VR or through actual visits to a marine site?
7. Have you shared what you did or learnt in this topic with anyone at home?
8. Do you want to learn more about the marine environment and conservation? Why/why not?
9. What did you find challenging in your learning in this topic?
10. What did you find challenging about using VR in your learning? Can you share some examples of the sorts of things you found challenging?
11. What advice would you give to a teacher who is planning to use VR in the classroom?
12. What advice would you give to other students who will be using VR in the classroom to learn about the marine conservation?
13. Is there anything else you'd like to share with us?

APPENDIX 4: GUIDELINES TO INFORM TEACHERS AND STUDENTS ON THE USE OF VR

VR guidelines for students

Virtual Reality — making it work for you!

What is Virtual Reality? Virtual Reality (VR) is a computer-generated digital simulation that can be similar to, or completely different, from the real world. VR uses special electronic equipment, such as a helmet or VR headset, a screen inside the headset, and sometimes a hand controller or gloves fitted with sensors.

How does it work? Each VR headset puts up a screen in front of your eyes so you are shut off from the real world. The visuals on the screen either come from an App on a mobile phone or from a computer connected to the VR headset via a HDMI. Users can interact with digital experiences in the form of games, 360 videos, or a combination of both.

What can it be used for? There are many possible uses of VR. VR can be used for playing games, other entertainment or for learning. It can be used for exploring particular locations and places such as mountains, forests, and the underwater world. VR can also simulate real workspaces for health and safety training, providing learners with a virtual environment where they can develop their skills without the real-world consequences of failing e.g., beginning to learn to fly a plane.

How can you get the best out of your VR experience?

VR is designed to immerse you in an experience to make you feel like you are really there! This means you often feel like moving around to make the most of the experience. But consider these ideas:

- If you have long hair, tie it up so that it will be out of the way of the VR headset.
- It is often safer to experience the VR while you are seated on the floor or on a chair. This will still allow you to move your arms and head but not bump into anything or fall down. If you need to stand and move, be sure to have someone watching you to keep you safe.
- Look AND listen carefully to watch what is on the VR headset. You can turn your head slowly to see what is around you.
- Experience VR with a buddy or an adult. As you can become immersed in the experience you can forget where you are so your buddy or adult can watch out for you. If you are being a buddy for someone else, it is important to talk to them clearly when you need to guide them to keep them safe.
- Stay calm and breathe normally while using VR. If you experience any discomfort when using the VR headset, gently take off your headset and rest on the chair you are sitting on. Let your buddy know you are not feeling well.
- When you have finished using a VR headset and have removed it, sit quietly for a few moments to help you adjust back to the real world.

VR guidelines for teachers

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How to help your students get the best out of their VR experience?

VR is designed to immerse someone in an experience. This means they can become disorientated, lose touch with their surroundings or become distressed. The following points should be considered:

You should consider the physical (motor and perceptual), cognitive, linguistic, emotional (affective), social and moral developmental stage of your students before using VR in your classroom. VR can evoke powerful reactions in children who may not be able to cognitively regulate the experience and, for the very young, they may come to believe that the virtual experience was real.

It is best to limit the use of a VR headset to no more than 15 minutes at a time, and generally less. VR is best used to complement a lesson, not take its place. Think about what you want students to get from the experience, for example whether it is to fuel their imagination or provide relevant and relatable content.

If students have long hair, ask them tie it up so that it will be out of the way of the VR headset.

It is often safer for students to experience the VR while they are seated. This will still allow them to move their arms and head but not bump into anything or fall down. If they need to stand and move, be sure to have someone watching them to keep them safe. Adults are quite cautious in VR but children are not! They like to stretch, spin around, look up and down, and they like to do this at speed.

So ensure students experience VR with a buddy or an adult. As you can become immersed in the experience you can forget where you are, so a buddy or adult can watch out for them. When being a buddy for someone else, it is important to talk to them clearly when they need to guidance them to keep them safe.

Provide a clear demonstration of how to fit and adjust the VR headset. If any student requires help with the headset or during the experience, ask them clearly if it is ok for you to help (except when the need is urgent). Talk through what you are doing so that they are aware of your intentions.

Using VR can make some people feel a bit dizzy or sick, particularly if they move their head around quickly, or get sore eyes. If students feel like this, they should gently take off their headset and rest on the chair they are sitting on or on the floor. Ensure they are supervised by a buddy or adult. There is no way to predict if a child might become cybersick and so it is important to educate students on identifying symptoms for early opt-out during VR sessions.

VR experiences can be very social for children. When supporting each other, even though they are not simultaneously in the VR experience, they may talk about the virtual space and guide each other through the experience and co-create their own stories around the content.

When students have finished using a VR headset and removed it, they should sit quietly for a few moments to help them to adjust back to the real world (especially before they engage in activities such as crossing roads, navigating stairs or riding bicycles).

After the session, check on your students' physical and emotional well-being.

[Note: Turn off the lights]