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**Varied experiences of science education in Auckland primary schools: Siloed, integrated, or somewhere in between?**

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# VARIED EXPERIENCES OF SCIENCE EDUCATION IN AUCKLAND PRIMARY SCHOOLS: SILOED, INTEGRATED, OR SOMEWHERE IN BETWEEN?

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## Abstract

*The way science education is positioned and practised in New Zealand primary schools varies widely. In this qualitative case study, participants in senior management from five Auckland primary schools were asked how they perceived science, how it was taught and reasons for the pedagogical approaches chosen. It was clear all schools were different in terms of population and the pedagogical approaches used to teach science. Science was taught in a range of configurations—from siloed to transdisciplinary integrative approaches and by classroom teachers, specialists and outside providers. The schools in this study who saw 'science as everywhere' and practised collaborative teaching were more likely to teach science through integration.*

## Keywords

Science; pedagogy; STEM; primary schools

## Introduction

Science is one of eight learning areas deemed important for New Zealand children to study (Ministry of Education, 2007). Rather than study each subject in a siloed fashion, the New Zealand Curriculum [NZC] states that students need to "make connections across the learning areas, values and key competencies" (p. 39). It further signals that learning through a connected or integrated curriculum and viewing the world through multiple perspectives is one way to enhance students' capacity to contribute to a rapidly changing society. Indeed, Rennie et al. (2012) assert that making connections across the learning areas and between the content, as well as making meaningful connections with learners and their worlds, is at the heart of curricular integration.

Rather than teaching science through its siloed disciplines of chemistry, physics and biology, science content may be taught through a STEM/STEAM approach. STEM/STEAM education began in the 1990s in the United States (Fitzgerald et al., 2020; Fraser et al., 2018) but has become a global phenomenon and part of the educational landscape in Australia and, to a lesser extent, New Zealand (Anderson et al., 2020; Fitzgerald et al., 2020; Granshaw, 2016; Hunter, 2021; Te Kete Ipurangi, n.d.).

Learning through STEM/STEAM is contested in how it is defined; the curricular areas included (Anderson & Li, 2020; Barkatsus et al., 2018; Mansour & El-Deghaidy, 2021), and pertinent to this paper, how it is configured in the classroom. Generally, STEM stands for Science, Technology, Engineering and Mathematics with 'A' denoting the Arts or design thinking if working in STEAM (Anderson & Li, 2020; Fraser et al., 2018; Tytler & Swanson, 2021). In this article, 'E' will also stand for the Environment. STEM education is defined by the Australian National STEM School Education Strategy (Education Council, 2015, p. 5) as "the teaching of the disciplines within its umbrella—Science, Technology, Engineering and Mathematics—and also a cross-disciplinary approach to teaching that increases student interest in STEM-related fields and improves students' problem solving and critical analysis skills".

A common way of describing curricular integration in STEM is through a continuum ranging from siloed subject areas to multidisciplinary, interdisciplinary and transdisciplinary integrated approaches (Hunter, 2021; Vasquez, 2014). In multidisciplinary integration, discipline boundaries are distinct with learning integrated thematically. Whereas curricular boundaries are blurred in interdisciplinary integration with learning blended through common problems or issues and may focus on skill

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development. In transdisciplinary integration the curricular boundaries are less apparent with learning framed through authentic real-life problems/ideas which are often based on students' interests (Drake & Reid, 2018; Hunter, 2021; Rennie et al, 2012; Vasquez, 2014).

While there are many ways of integrating the curriculum, according to Rennie et al. (2012), what determines whether the curriculum is integrated or how it is configured, is the "school context" rather than ideological or philosophical views of learning (p. 20). However, Smith et al. (2020) assert that cultural expectations, and differing views of teachers' role in education, do affect how the curriculum is integrated.

The exact balance of the curricular areas incorporated in a STEM experience varies. Fraser et al. (2018) state that science and mathematics tend to dominate the teaching and learning experiences. Hunter (2021) asserts that only integrating two curricular areas is not a genuine STEM experience, as it is limited in scope. In this argument, she aligns with English (2016), who argues it is important that all the disciplines receive equal billing. Vasquez (2014) alternatively contends the true value of the experience is to provide scope for the students to "apply the skills and knowledge they have learned" (p. 12); thus each discipline does not need to be included in every experience.

Ideally, STEM education should mirror the practices of scientists, engineers and technologists and their ability to draw on multiple skills and knowledge bases to solve complex problems (Granshaw, 2016). However, it is also crucial that students gain a deep conceptual understanding and skills in a discipline, whether it is taught as part of an interdisciplinary approach as advocated by Fitzgerald et al. (2020) at primary level, or alongside a STEM unit at secondary level (Granshaw, 2016). What can make the difference in whatever configuration is chosen, is the mastery of teachers in developing teaching sequences that support learners to explore complex problems using either a trans-, inter-, or multi-disciplinary approach (Hunter, 2021). This mastery also includes their ability to work in a collaborative co-teaching environment, managing planning, teaching, assessing and interpersonal relationships to optimise learning (Thousand et al., 2006).

The promotion of STEM as an educational approach and pathway into future STEM careers is encouraged by many governments (Hobbs et al., 2018; Te Kete Ipurangi, n.d.; Tytler & Swanson, 2021). This is due in part to governmental concern over students disengaging from science as they progress throughout their education, decreasing student achievement in science and non-progression to STEM-based careers (Fitzgerald et al., 2020; English, 2016; Hobbs et al., 2018; Moeed & Kaiser, 2018). Learning through STEM/STEAM has been offered not only as a panacea to student disengagement from STEM subjects, but also as a possibility to enhance science content learning and skills, such as critical thinking and problem solving (Anderson & Li, 2020; English, 2016).

In the New Zealand setting, STEM/STEAM is an endorsed approach by the Ministry of Education (Te Kete Ipurangi, n.d.), where rather than learning curricular content in siloed subjects, students inquire into authentic problems using a creative, active, integrated approach to enhance critical thinking and discussion. It can also enhance students' problem-solving skills, creativity, communication skills, and engagement, as well as enhancing content knowledge (Anderson & Li, 2020). It is also advantageous because it shares power, enhances student autonomy and can be framed holistically and support authentic culturally responsive pedagogies (Drake & Reid, 2018; Fraser & Paraha, 2002; Wilson, 2020). This is important as our students need to be able to make informed decisions about a plethora of information in the world in which they live. However, it is not without its challenges, as working in this way, especially at secondary level, can be constrained by the tyranny of assessments, timetabling and an extensive curriculum (McDowall & Hipkins, 2019).

It is timely to ascertain what is happening in our schools in these disciplines and determine what factors underpin the pedagogical choices chosen by management to support student learning. The data in this article was drawn from a study that explored how science education is positioned and practised in five Auckland primary/intermediate schools. A wider lens was applied to the data to see if the STEM subjects of technology, engineering/environmental education and mathematics were mentioned by the participants and, if integration was mentioned, how it was practised.

## Methodology

This paper reports on data from an ethics approved interpretive qualitative case study that interviewed participants from senior management in five diverse Auckland primary/intermediate schools. An email was sent to primary/intermediate schools in the Auckland area asking for permission to interview a senior management team member about how science was taught in the school. Conducted under COVID-impacted conditions, only five participants agreed to take part. For ease of operation, and to protect participant identities, both participants and the schools are referred to by te reo numbers as pseudonyms.

There were two main questions posed to participants. with subsidiary questions derived from them:

1. How is science taught at your school?
2. What are the reasons for your choice of pedagogical approaches in teaching science?

Data were generated in semi-structured interviews of between 40 and 60 minutes. Additional information was drawn from school websites and the Education Counts (2021) website.

Literature relating to primary science education in New Zealand, such as the Trends in International Mathematics and Science Study [TIMSS], was used as a deductive basic for initial codes to categorise data, such as teaching time, and professional development. The codes, or nodes as NVIVO terms them, were used to attach pertinent text from the interviews and to identify patterns, which were collated into larger themes which encapsulated the essence of the "data in relation to the research question[s]" (Braun & Clarke, 2006, p. 82). The themes created at the nexus of the "data, analytical process and subjectivity" (Braun & Clarke, 2019, p. 594) were used to create a narrative about science integration in these five schools.

## Description of schools

Table 1 below outlines whether the schools are primary (Year 0–6), full primary (Year 0–8) or intermediate schools (Year 7–8). It identifies the decile rating or measure of the socio-economic status [SES] of the community in comparison to other schools in the country and ethnic groups of the community (Education Counts, 2021). The description of the community and classroom structure are drawn from participant comments. This was supplemented with data from their websites to create a rich description of the school.

All the primary/intermediate schools in this study are unique and cater to different communities with differing needs and expectations. They are positioned in different SES communities and have diverse populations. The learning environments range from single cell classrooms to Innovative Learning Environments (ILE), with at least one school highlighting a transition.

**Table 1: Description of the Schools**

| School | Year Level | Decile | Ethnic group percentage<br>Māori, Pacific, Asian, European/ Pākeha. | Description of community | Classroom structure |
|---|---|---|---|---|---|
| Tahi | 1–6 | 2 | 24/39/25/3 | Multicultural—large Pacific population.<br>Working poor. | Single cell & ILE. |
| Rua | 1–6 | 10 | 7/1/21/61 | Predominantly European/ Pākeha, high socio-economic status [SES] parents. | Mostly single cell, a few with sliding doors between them. |
| Toru | 1–6 | 2 | 16/25/15/35 | High Māori/Pacific Islander population.<br>Rapidly growing area. | Single cell & ILE. |
| Whā | 1–8 | 10 | 5/5/45/35 | Ethnically diverse high SES parents with traditional views of education. | Flexible learning environment/ILE. |
| Rima | 7–8 | 6 | 14/8/20/54 | Rapidly changing community —large infill housing area.<br>A general school. | Single cell moving to collaborative future focused way of learning. |

## Findings

The participant interview and website data are explored under three themes. The first outlines how science was positioned in the schools and the pedagogical practices used by the schools. The second describes the extent of integration and inquiry used in the case-study schools. The final section interrogates how integration occurs in the STEM disciplines.

### *The positioning of science and pedagogical approaches used in the case study schools.*

The way science was positioned, and the pedagogical practices used varied between the schools. Their responses are summarised in Table 2.

Science was conceptualised differently by each participant. Two participants described it as "being everywhere", while the other three positioned it as a curricular subject. It was taught by a variety of people, such as the classroom teacher/s, outside-providers and specialist science teachers. All participants either spoke specifically of linking it to the New Zealand curriculum [NZC] or alluded to it. Some science was taught in a siloed manner or blended with other curricular areas into an inquiry project or overarching concept, or in concert with community groups.

The priority of science in the schools varied. There had been little professional development in two of the schools, but Toru had identified they needed to raise the profile of science and noted that accessing science resources was problematic, as they "don't have a budget for science". Both Toru and Whā schools had not heard of the Science Learning Hub. Three of the schools either had recent science professional development (Tahi), access to science expertise through specialist teachers (Tahi and Rima) or drew on outside expertise through networks (Tahi and Whā), such as Kāhui Ako and local high schools. Whā and Rima had also established strong networks with the local community to develop students' interest in science.

**Table 2: How Science is Positioned and Practised**

| School | Position of science in curriculum | Pedagogical practices and resources used in class | Science professional development [PD] | Additional science-based programmes |
|---|---|---|---|---|
| Tahi | Teaches whole curriculum but with a strong emphasis on science. | Wonder table.<br>Science boxes.<br>Classroom teacher.<br>Support by teacher in charge of science with Nature of science and science skills. | Kāhui Ako literacy learning with a science focus.<br>Previous Professional Development [PD] by experienced outside science specialist. | Enviroschools.<br>Garden to Table.<br>Makerspace each class goes through each term. |
| Rua | Linked to NZC.<br>Focus determined by what has not been taught recently and student interest. | Team planning.<br>Some planned inquiry.<br>Delivery varies.<br>Taught by everyone. | Little recent PD<br>"Reading, writing and math took precedence over everything and science got kicked down the road."<br>"Getting rid of science advisors … was a mistake." | None stated. |
| Toru | Aspects of science.<br>Linked to context strands. | Taught by hub teachers. Next year major science focus—Term One—Living World—my brain is a miracle. | Recognised need for more science.<br>No PD recently. | Outdoor providers visit school.<br>Zoo trips<br>"Don't have a budget for science." |
| Whā | Science is infused across everything we do.<br>Linked to NZC.<br>Epistemic knowledge.<br>Scientific capabilities. | Taught authentically.<br>Use "overarching concepts" such as 'identity' to underpin learning.<br>Generally organic based on problems and dilemmas.<br>Also taught in a pure "explicit" manner to enable students to "grow understandings, knowledge and scientific capabilities" in areas they are passionate about. | Can use facilities and expertise at local high school if required. | Connected to local community—projects like community gardens. |
| Rima | Science is everywhere. | Specialist teacher teaches topics such as Electricity.<br>Learn through STEAM where teachers blend elements of whatever project-based learning they are working on at the time.<br>Individual projects such as chicken coops, or exploring local environment. | Forthcoming makerspaces. | Connected to local community redevelopment project. |

## Integration and inquiry

Any allusion to integration was drawn from the data (see Table 3) to see what curricular area/s were integrated with science and how the integration occurred. Firstly, general data on integration are explored, then the areas relating to STEM are explored.

Integration was mentioned by all participants, but the configuration varied considerably. Science was generally taught as a siloed subject in Rua school. In Rima school, some science was siloed, especially when taught by the specialist science teacher (Table 2), as it was important preparation for high school. However, integration was explicit when taught as part of a STEAM unit, which is a form of project-based learning that blends different curricular areas.

Science was often combined with other subjects; however, they are not necessarily STEM disciplines. Integration was reported as the norm in Tahi, Toru and Whā schools. In Tahi school, integration was either through the classroom teachers making links to other areas, in the makerspace, or as part of Enviroschool's philosophies which are underpinned by te ao Māori. Science was usually combined with another curricular area, such as PE, in Toru school. Integration was common at Whā school with students learning authentically through exploring problems and issues over long-time periods, supported by strong community connections, such as local iwi.

Participant views on the value of integration varied. The participant from Rua school was concerned integration diluted learning as it "became too general". Alternatively, the participant from Whā school asserted it deepened learning as the students were

> empowered … to tackle some of the issues [of society] … making sense of the world around them. They were able to innovate and problem solve [and] elicit beautiful questions and test their assumptions … to understand the world as a scientist.

The two schools that espoused the 'science is everywhere' philosophy (Whā and Rima) usually taught it through integration, apart from when the specialist science teacher taught it, or as the participant from Whā school states, when explicit teaching was required either of the "science capabilities … or key scientific epistemic type knowledge … or scientific processes". This showed there is a link between how the school perceived science, the pedagogical approaches used and how integration occurs in the classroom.

### Table 3: How Integration is Structured

| School | General integration | Curricular area integrated | Other aspects |
|---|---|---|---|
| Tahi | Across the curriculum. | Kāhui Ako literacy learning extension.<br>MakerSpaces. | Māori perspectives are a guiding principle in Enviroschools. |
| Rua | Important connections be natural, "not forced". | Might be integrated with reading, written language and perhaps mathematics. | "We don't do the whole integrated thing because what we found was that no one was winning at that point. It just became too general." |
| Toru | An overarching curricular area [and a] minor strand, so it might link to PE and Science. | Science is usually taught with maths, technology … those three go together and highlight each other. | Consultation with Pacific parents—science traditional food, growing, planets. |

| | | | |
|---|---|---|---|
| Whā | Science is everywhere—all the time.<br>Integration is a natural fit. | Having longitudinal projects means that can go deeper into the learning and "bring in the mathematics, the English and everything else".<br><br>Ways that science is integrated include bringing in "iwi to look at DNA", being involved with community groups in "gardening, growing produce, and selling it". | Some parents want the siloed approach to teaching. |
| Rima | Well established. | "Science [incorporated] into classroom units through STEAM." | The participant wants the students to "make the science behind the solutions for the problems society face [and] be entrepreneurial" with the school providing the "facilities for everything to be blended". |

## Connections with technology, engineering, the environment and mathematics

This section examines how the other disciplines of STEM (technology and engineering, mathematics), and the environment are interconnected with science in the schools studied. Table 4 outlines participant data on the other disciplines of STEM.

Three aspects of technology were mentioned by the participants, the digital component—for example, coding, using machines like robots and Tinker cars, and makerspaces, where students work like engineers designing and creating projects as a means of engaging with technological processes. Technology was either taught by itself or combined with two other curricular subjects like science and mathematics. The engineering aspect was alluded to through makerspaces and working in STEAM. One participant considered technology taking precedence as the favoured curricular area.

The environment was identified as important by four out of five schools. Three schools mentioned the environment or sustainability. Two were positive about the focus, while the other considered that it was not necessarily taught well, and increased focus on 'pure science' would be optimal.

**Table 4: Interconnection of Science with Other Components of STEM**

| School | Technology/ Engineering | Mathematics | Environment |
|---|---|---|---|
| Tahi | "Set up a MakerSpace room … The idea is that there's a particular book that the whole school focuses on and reads … for example on sustainability, so there's activities to do with that and there are some other coding type activities." | Not specifically mentioned. | Enviroschools.<br>Garden to Table. |
| Rua | Robots.<br>Technology seemed to take precedence once the national standards numeracy and literacy pressure was relieved rather than science. | Not specifically mentioned. | "I feel sustainability is overdone and not done well when it is done … I would prefer to get onto something that is more pure science." |
| Toru | Science, mathematics and technology usually integrated.<br>"In our school for STEAM [we get a] scenario, and work in construction groups … link it to a book." | | "Have just developed a garden [and want to develop] a community garden [and move towards] garden to table [and becoming a] green school."<br>Want to recycle. |
| Whā | Partnership with recent arrival from Singapore who is "bringing tinker carts" to the school, and "there's tech and science involved".<br>Staff are engaged in digital learning. | Not specifically mentioned. | Focus on sustainability and there is a strong connection to the environment and the "students work alongside experts" in the community, ideally pursuing a project that is based on "their interests [and] passions." |
| Rima | Construction and integrated MakerSpaces.<br>International projects in computer science.<br>Developing resources for third world countries. | Not specifically mentioned. | Many teachers are "environmentally focused".<br>There is a teacher involved with "Tiritiri Matangi Trust [native bird wildlife sanctuary]", a "horticultural area", and students are included in "greenway development". |

## Discussion

There appears to be a connection between how science is positioned at each school, and the pedagogical approaches employed. Therefore, examining the composition of each school, the positioning of science, and whether it is taught in a siloed manner or using an integrated approach provided a framework to view the interconnections.

## School composition

The schools involved in the study came from different areas of Auckland and ranged from decile 2–10. Their communities were diverse culturally and ethnically with differing social and educational priorities and perspectives. For example, it was important for Rimu school students to be prepared for high school, so they had classes from a specialist science teacher, while the parents at Toru school wanted science content related to their Pacific culture. As each educational context was unique, the pedagogical approaches and topics/themes explored were unique (Rennie et al., 2012).

## Pedagogical approaches

All five study schools were passionate about providing valuable educational experiences in science for their students. The schools that did not have specialist science teachers, ready access to science experts or had undertaken recent professional development were constrained by their own confidence in science and knowledge of scientific resources, such as Science Learning Hub, and funding for science. Concerns were voiced about lack of funding and ready access to science advisers.

The pedagogical approaches ranged from siloed lessons teaching explicit concepts to science contained within topics and learning organically through exploring ove-arching concepts or issues. It is clear all study schools attempted to link different curricular areas (Ministry of Education, 2007) and had a desire to make learning authentic and help the students connect to their communities (Rennie et al., 2012).

Schools that viewed science as a curricular subject were more likely to teach the STEM subjects in a siloed manner, perhaps indicating a desire to ensure content was well understood before adding in the additional complexity of using integrated pedagogies. If they integrated subjects, it was generally only with another one or two areas which, according to Hunter (2021), is limited in scope, However, perhaps choosing that option was drawn out of desire to make integration manageable, and focused rather than 'forced', and tokenistic. There were several instances of schools using a thematic approach, which would position integration within a multi-disciplinary approach (Vasquez, 2014).The schools that viewed 'science as everywhere' and taught in an ILE using modern pedagogical approaches were more likely to integrate the different components of STEM or utilise a problem that connected the differing curricular areas authentically, and work within a transdisciplinary approach (Drake & Reid, 2018; Hunter, 2021; Rennie et al., 2012; Vasquez, 2014). This may be because teaching collaboratively and using interdisciplinary approaches are the norm in ILE spaces, or that the desire to create authentic learning may possibly lend itself to a more interconnected way of learning. However, it must be noted that all the schools were pragmatic and chose the approach that supported the needs of the students at the time, whether it was explicit teaching or problem-based learning.

## Integration with other curricular areas

Integration was occurring in all the schools between science and other subjects, not just STEM subjects. All schools taught about the environment. Technology and engineering were identified in terms of makerspaces and using equipment like robots and highlighted as part of a recent focus. Mathematics was not specifically asked about but was mentioned as a natural connection. Simply ticking boxes to integrate or work in STEM may not necessarily enhance student engagement, or support teachers' enjoyment or coverage of the curricular areas. If the connections between these curricular learning areas are weak or coverage of concepts and skills is limited, students may not develop knowledge let alone the skills needed in all the curricular areas (Hunter, 2021). If integration is to be successful, it should be framed authentically (Fraser & Paraha, 2002) and include strong connections to the lives of the students and the places they live (Wilson, 2020).

It appeared that it was not easy to meaningfully integrate other curricular areas. Several schools mentioned their connections with either te ao Māori or their Pacific community, indicating their desire to support culturally responsive pedagogies (Fraser & Paraha, 2002), but this is a developing area. The schools were clear in their connections to their local communities (Rennie et al., 2012), some mentioning involving parents of students or being involved in activities like community gardens. This provided a chance for the learning to be authentic and for the students to "apply the skills and knowledge they have learned" (Vasquez, 2014, p. 12), and to quote the participant from Rima school, help students to realise science can hold the "solutions for the problems society faces", and spark an entrepreneurship that may transition the students into a science or STEM trajectory (Hobbs et al., 2018; Te Kete Ipurangi, n.d.; Tytler & Swanson, 2021).

## Conclusion

As highlighted in the New Zealand curriculum (Ministry of Education, 2007), it is important for New Zealand students to not only understand scientific concepts and the processes of science, but also develop their critical thinking skills and capacity to contribute to society as informed citizens. Learning science through integration, or through STEM or STEAM, is one way for students to deepen learning and broaden their perspectives of the world.

The study showed that while science was mainly taught by classroom teachers, it was supplemented by expertise from specialist science teachers and outside providers. The teaching of science varied from science taught as a siloed subject, to being integrated thematically, or using a transdisciplinary model (Vasquez, 2014). It was clear that which curricular subjects were integrated with science were based on expediency, rather than strict adherence to STEM/STEAM choices.

Schools that had prioritised science through recent professional development, and had knowledge of pertinent science resources and support from science experts, were more likely to take risks with their science teaching and integrate science with other curricular subjects. Working through integration was stronger in schools with senior management who viewed 'science as everywhere', and who utilised collaborative teaching approaches. These schools were more likely to be teaching the key science ideas through making meaningful connections between curricular areas and their students' worlds (Rennie et al., 2012).

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