Teachers and Curriculum

Journal website: http://tandc.ac.nz

ISSN 2382-0349

Published by the Wilf Malcolm Institute of Educational Research

Wilf Malcolm Institute of Educational Research
Te Pātahi Rangahau Mātauranga a Wilf Malcolm
THE UNIVERSITY OF WAIKATO

Teachers and Curriculum, Volume 21 Issue 2, 2021.
Special Issue: *Quality STEM education*

STEAM integration

Simon Taylor & Paul Lowe

Special Issue Editors: *Elizabeth Reinsfield, Chris Eames & Wendy Fox-Turnbull*

To cite this article: Taylor, S., & Lowe, P. (2021). STEAM integration. *Teachers and Curriculum, 21*(2), 45–53. https://doi.org/10.15663/tandc.v21i0.382

To link to this volume: https://doi.org/10.15663/tandc.v21i0

STEAM INTEGRATION

SIMON TAYLOR & PAUL LOWE
The University of Waikato
New Zealand

Abstract

There has been growing interest to establish curriculum integration in secondary schools due to the promotion of relevant contexts used in programmes. This study examined the role of a STEAM programme with junior secondary school students, using a future-focused inquiry which included Science, Environmental studies, Technology, the Arts, and Mathematics. To explore the potential role of STEAM programmes, a group of teachers from a New Zealand and a Japanese international school participated in a short-term research intervention. While curriculum integration has been a feature of learning in many primary schools, secondary teachers, who are usually subject specialists, are faced with the challenge of how to design and facilitate cross-curricular inquiries using STEAM. To meet this challenge, the teachers and curriculum developers considered the interface between their conceptions of cross-curricular inquiry and taking practical steps to implement such a programme. The study investigated pedagogies to develop skills in cross-curricular project work and new themes to exemplify integrated STEAM learning.

Keywords

Cross-curricular inquiry; integrated STEAM; teaching and learning.

Rationale for developing STEAM inquiries

A curriculum development project, working collaboratively between one school in Japan and one in New Zealand, emerged from the challenge of exploring how curriculum integration could be used to establish Science, Technology, Environmental studies, the Arts, and Mathematics (STEAM) subjects in Year 9 classes. Curriculum integration has not been a strong tradition in secondary schools, as teachers are usually qualified as subject specialists, and individualised subjects are taught in isolation (Brough, 2008). Teachers have tended to be less enthusiastic towards the implementation of cross-curriculum inquiry, identifying the challenges of not knowing how to, and not having the opportunity to, trial different pedagogies (Bolstad et al., 2012; Dowden, 2012). However, there is a growing interest in STEAM integration in secondary schools (Boyd & Hipkins, 2012) and a global concern for improvement in cross-curricular education as an integrative skilled workforce is critical to meet economic and creative challenges in the 21st century (Partnership for 21st century skills, 2017). Furthermore, as integrated fields expand and increase demands for workers skilled in cross-curricular subjects, it is difficult to predict all the workforce skills and knowledge necessary to remain competitive (English, 2017). For example, there is a worldwide challenge that requires collaboration with specific knowledge expertise across STEAM fields to be able to design and implement effective solutions (OECD, 2018) on the effects of climate change.

The purpose of the study was to explore themes to exemplify integrated STEAM inquiries so that there was potential for the schools to develop a junior programme, which could continue at other year levels. We had an understanding that teachers can have a significant influence on student interest in, and understanding of, an integrated context (Autenrieth et al., 2017). Teachers can, however, often focus on the subject knowledge they are comfortable teaching and sometimes ignore crucial links with other knowledge systems. Therefore, when teachers lack confidence in incorporating a STEAM inquiry, they may, in fact, potentially limit students' exposure to a full breadth of conceptual knowledge across the curriculum areas. There are important learner benefits of curriculum integration, which include helping students link discipline knowledge across a range of subjects and where the learners draw on issues of global and personal significance using connections (Fraser, 2000). Integrating STEAM is more than a blend of two or more school subjects, it requires a complex system of pedagogical approaches based

Corresponding author
Simon Taylor simon.taylor@waikato.ac.nz
ISSN: 2382-0349
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around an overarching context or issue (Nadelson et al., 2012). The issue, need or problem is identified, discussed, debated and negotiated by teachers and students (Rennie at al., 2013). In this study identifying pedagogies to develop student skills in a cross-curricular setting was seen as critical for the teachers to build on and this could be scaled up for school wide implementation. A conceptual model of STEAM integration was developed, and this too may help to facilitate practical and operational school systems, such as timetabling and programme design.

Research design

This study involved two schools over a six-week cross-curricular STEAM inquiry, using the theme of recycling and sustainability at the New Zealand secondary school, and the theme of keeping ourselves safe in a tsunami at a Japanese international school. The study set out to identify trends emerging from the data (Tashakkori & Teddlie, 2003), which included audio recordings of teacher meetings of weekly sessions of one–two hours duration and from journals in which the teachers documented the lessons over a six-week timeframe. Using the journal, the teachers were invited to reflect on their developing understanding of STEAM integration by noting how the inquiry was planned and what specific pedagogies were identified in the lessons. The journals were structured so that the teachers used them as both a planning document and a reflective diary. The research was grounded in the sense that the researchers were initially open-minded in their approach by seeking to investigate curriculum integration to enable a cross-curricular inquiry to take place.

Both schools had a class at the Year 9 level (13–14-year-olds), with 36 students at the New Zealand secondary school, taught by three teachers, and 44 students at the Japanese school, who were taught by seven teachers. The classes had three lessons of 75–100 minutes in duration per week, and the teachers had curriculum specialism in science, technology, health, social studies and mathematics. Qualitative data were gathered through the use of audio recordings of the meetings, which were transcribed and analysed in identified themes. The data analysis employed grounded and mixed techniques (Braun & Clark, 2006). The journals were reviewed to identify key themes and trends evident in the teachers' reflections. The researchers then met to discuss ideas about a suitable coding protocol for an analysis of the journals and audio recordings. The key items for analysis were identified, as follows:

- The way the teachers identified and expressed their understanding of STEAM and ways in which they interpreted curriculum integration in the inquiry.
- The selections the teachers made of particular learner competencies that they documented in their journals.
- The particular responses teachers made in recognising and explaining STEAM integration as a pedagogical model to facilitate an inquiry in a classroom setting.
- Any other items of interest commonly raised.

Findings

Four key coding headings were used to assemble detailed data from the audio recordings and the teacher diaries under each heading. This was accomplished using a grounded approach to allow trends to emerge from the data. Further meetings with the researchers and the teachers took place to review emerging findings and to establish any sub-codes within each of the four key code headings. For example, under heading two, what type of competency was identified or used in their lesson by the teacher. Thus, the researchers were able to identify and record the importance placed on specific STEAM competencies. While at this point the coding was relatively established, we were still open to the possibility that new categories could emerge from the data as the analysis continued. At the same time, each of us identified key ideas exemplifying main themes and trends. These ideas were highlighted so that they could be used to provide a conceptual representation into the facilitation of a STEAM inquiry.

Teacher interpretations

This study involved the teachers and researchers in designing cross-curricular learning experiences for the students. Our initial task was to define what STEAM means in the context of curriculum areas. When students are exposed to science as a subject at school or it has relevance in their life outside of school, it is often related through skills or products (Taylor & Jones, 2020) and is usually difficult to separate from other STEAM subjects. The teachers decided that STEAM is most usefully framed by its role in addressing real-life problems and proposing coherent solutions. The learning experiences were designed to have the objective of developing skills that enabled the students to navigate between the individual STEAM subjects. This STEAM competence developed useful connections between the discrete subjects in the context of authentic problems or questions. As the STEAM inquiry proceeded over the six weeks, specific design phases were noted. The initial phase drew on real-life and current contexts where students were invited to view short video clips/images and discuss ideas about them. The second phase, which was longer in duration, prioritised STEAM competence over learning through subject specialisation. This competence placed emphasis on generic skills, such as collaboration, communication, presentation, the specific roles in the teams, and using evidence to make claims using a range of curriculum areas of STEAM. When the teachers reflected on their initial lessons, there was prominence placed on ensuring the overall inquiry questions were well understood by the students. Teachers commented on the value of providing opportunities such as the videos, static images and drawing of mind maps early on,. This was to encourage student reflection and dialogue about their prior knowledge on the inquiry context. This was signalled by the teachers so that they could get a sense of student understanding early on and make plans for future activities. Towards the end of the study, the teachers discussed the importance of being open to their changing role in the classroom. The roles of teaching took on different pedagogies, and these were noted through the journals and meetings, including teacher as mentor, listener, manager of resources, facilitator and co-researcher. As two teachers said:

> The inquiry context on sustainability required me to be much more flexible with the curriculum areas. Just in terms of planning activities and [being] mindful of student ideas. For instance, we couldn't get locked only on science and ignore the importance of the debate coming up. It was about the question: *Should we rethink, reuse, recycle bottles?* Many of the students hadn't been in a debate before, so we had to show them the formalities of debating. We also needed to be open to new content knowledge and be able to quickly act on emerging ideas from our students, for example, helping them with the interpretation of graphs of carbon dioxide levels and air temperatures. (Teacher 1)

> We were busy, checking in with students constantly, much more than if we were teaching a single subject. I think because the inquiry was more open, there was much more opportunity for the kids to perform or take part in role play or build a model. So a much wider variety of activities going on in the lessons. I found that sorting out materials and organising gear needed to be done well before a week started, students would identify what they needed, making lists etc., I would help them with this. (Teacher 2)

One particular aspect noted was that the teachers remarked how student confidence grew in asking questions. At the start of the inquiry, teachers said students were not accustomed to developing carefully constructed questions. However, by the end, the teachers said many of the students had gained confidence in group discussion and whole class discussion through the process of robust questioning. They also said that the nature of learning was more about the students drawing out knowledge from a range of sources and less emphasis on them as a teacher providing a repository of answers to student questions. What was observed in the journals was the teachers wanted to build further collaborative action in the class to encourage students to talk more and write down their ideas. They noted that their lessons required additional time to set up groups and sort out personality issues in the class. On occasions, teacher challenges arose from tensions between the need to encourage student pursuit of their own questions and provide greater student autonomy, but also the need to step in, guide and pose further ideas. Two teachers commented:

> By the end of the inquiry the students were able to ask good questions, work together and use evidence to express themselves. I think these were the real highlights of the STEAM inquiry. I know our students are now much better at working happily as a class. They have certainly laughed more doing the skits, and they have learned how to take an issue and talk with confidence about it. (Teacher 1)

> It was difficult to know when the right time to check in with students and give them more guidance but at the same time not become too controlling and dominating. I had to find a balance of listening to them and then coaching next ideas for them. (Teacher 2)

Developing STEAM competence

The theoretical framework for the study was based on a larger framework for integrated STEM education (Kelley & Knowles, 2016). We theorise that curriculum integration of STEAM subjects helps to support teachers in developing their understanding of how their students learn and how much they can learn (Fraser, 2000), and offers students the opportunity to access specific knowledge from a range of curriculum areas. When teachers employ curriculum integration across the STEAM subjects, Beane (1997) maintains that relationships are strengthened; however, the roles of teachers and students can be challenged in the process. A model of STEAM integration (see Figure 1) was developed with the teachers; it is a visual representation of what was integrated into the subsequent teacher discussions. This exercise was challenging; juggling theory with classroom reality fuelled with teacher dialogue. However, the discussions proved valuable in that the teachers could develop their own interpretations. The diagram helped to assemble and affirm important ideas so links could be made with pedagogy and curriculum integration. Made up of four sub-sections, it describes *Student centred,* which was identified to develop students' ability to take responsibility of an inquiry and make decisions about how the inquiry should proceed. Here the students begin to manage their own team, usually in groups of 2–3 members and where the role of the teacher is that of a facilitator, to listen and identify any issues that arise, and encourage students to resolve these themselves.

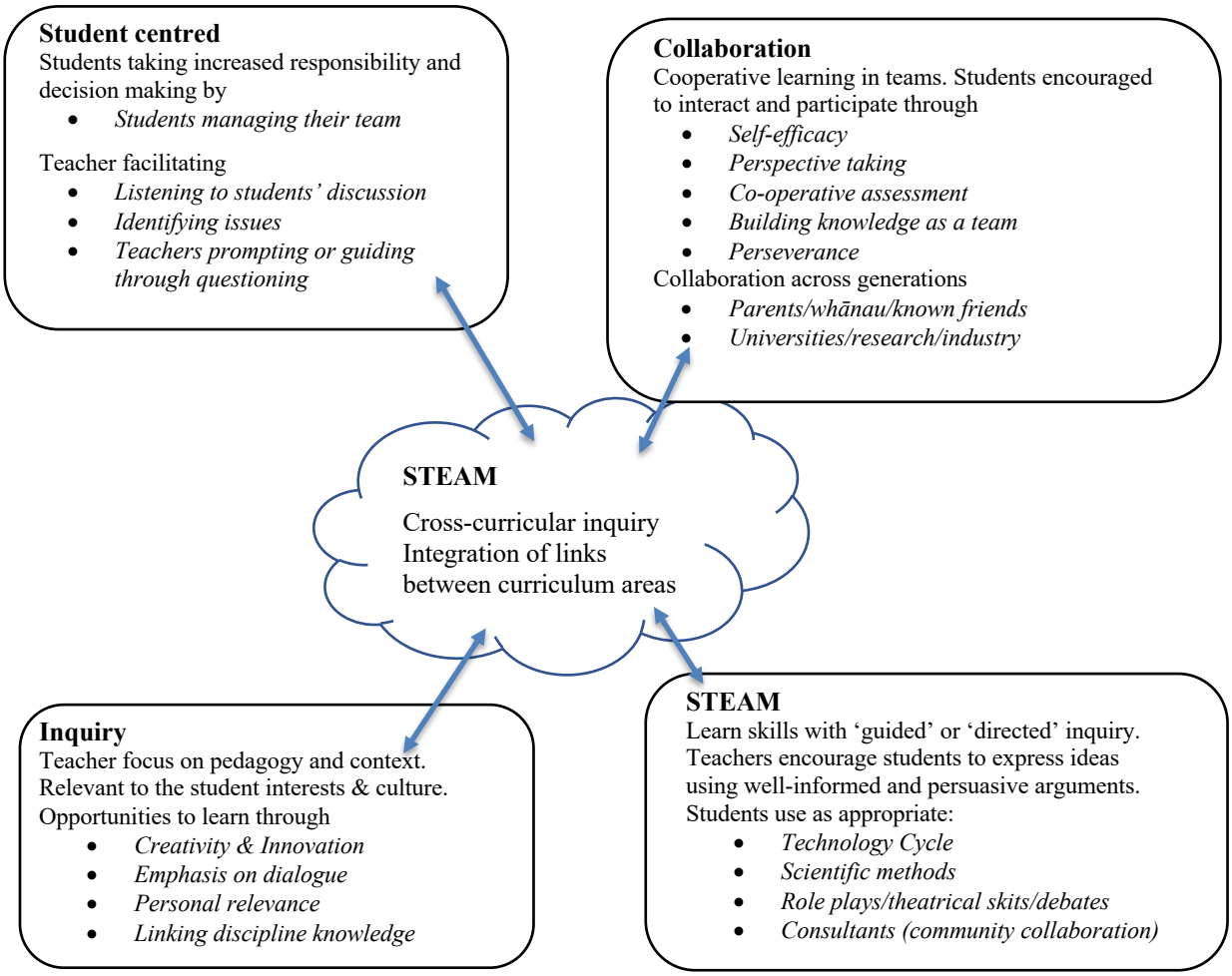

Figure 1: A conceptual framework for STEAM integration.

Members of the group and the class have a responsibility in *Collaboration* to work cooperatively as a team, collect evidence from a range of sources and build knowledge together to inform themselves about the inquiry. Cooperative Learning Assessment (Lowe, 2004) was encouraged, where students are given the opportunity to be assessed together and the summative assessment is shared between the group members. Collaboration of the learning can also be shared by family/whānau, where parents or grandparents and the wider community can be involved in the inquiry process. The developing *Inquiry* is relevant to students' interests and culture and has the opportunity to be creative through both scientific investigation and artistic endeavours. Most importantly this is where the students develop ideas through the use of visual media, three dimensional sculptures (see Figure 2), practical investigations, dioramas, theatrical skits (see Figure 3), and with importance placed on dialogue when using the various media. Here the students have the opportunity to improve ideas, where they have insight to progress from their own ideas and conceptions to considering other perspectives, especially scientists' and artists' views. Creativity and innovation are at the centre of this section, where students can go beyond reproducing knowledge and begin to develop their understanding through the process of the inquiry. *STEAM competence* uses contexts that expose the students to situations where they are motivated to ask personal decisions and judgements connected with an issue. The issue can be a need or question generated by the student's own passion and interest. Or the inquiry can be guided more by the teacher, where direction can support the learning process through guided steps where there is negotiation of ideas between the teachers and the students. Students can use technological or scientific methods to support them in their inquiry. The four sections of the integrated STEAM model take place in the inquiry process, where new ideas and questions can be formulated through the student experience.

Figure 2: Students building models of bridges to discuss strength and design in the tsunami inquiry.

Figure 3: Students developing roles in theatrical skits: Making props and models.

Themes

Themes were developed to go beyond single subject boundaries, where relevance and 'real' world contexts were considered important to incorporate. The study explored two themes: *How good is New Zealand's recycling programme and next steps for sustainability?* And *How do we keep ourselves safe in a tsunami?* Focusing on human ingenuity, design and process, students explored a positive and sustainable future. A series of activities centred on transport, waste, pollution and future technologies with regard to the recycling theme, where students could re-design products. The teachers spoke fervently about the need to design an umbrella topic that had an open-ended context to it. This took time to prepare and plan for, but the effort was rewarded by overall positive student engagement. It meant that there needed to be some specific background knowledge that was highlighted within the context of the inquiry. However, the teachers stressed the importance of encouraging diverging inquiries from the main context of the theme, where student autonomy was encouraged and opportunity for students to pursue their own personal questions was facilitated.

Teachers take on STEAM

Feedback from the teachers suggest that the study has been successful in providing an opportunity for them to have a voice in discussing curriculum integration using STEAM. The teachers found the resources, such as the video clips of student voice and senior projects, valuable, which helped provide ideas and teaching strategies. Teachers commented that STEAM integration offered differentiation in terms of a range of pedagogies, specifically where students needed to be encouraged to work in small groups (see Figure 4), which helped to improve discussion and cooperation between students. Teachers noted that students who actively engaged with the inquiry process found the activities more relevant to real-life issues, and they particularly enjoyed the openness of the inquiries where debating, model making, theatrical skits using role plays, and group discussions took place. Teachers were asked to report on how their STEAM inquiry compared with regular classes of mathematics and science lessons. Their answers varied because of the different ways in which the two schools had developed each inquiry. However, in general, the teachers found the themes to be clearly related to STEAM curriculum subjects, involving the students with activities not typical with their regular classes of science. They also commented that their students had been provided with far greater opportunities for perspective-taking compared to individual subject lessons. As one teacher said:

> I found the STEAM inquiry provided the chance for our students to see connections between the subjects; it related to current issues to their school life, home life. This was motivating, realistic, and they had experiences to put their understanding into an action. I felt the students had to involve social, ethical and even political points of view which linked the science, maths, technology etc., which I believe are benefits from using STEAM. By the end they were responding to questions that required quite complex social issues and with greater awareness of community and society.

Figure 4: Collaboration on the sustainability inquiry investigating plastic decomposition.

Teaching the STEAM integration programme remained challenging for the teachers. It involved not only engaging with new topics, such as the sustainability or tsunami themes, but also new pedagogies. Professional reflection for teachers was made available through the series of weekly reflection episodes. Although the teachers found these sessions valuable, sometimes there was a tendency for discussions to shift to the challenges in the study, such as constraints of lesson time, or poor group dynamics with students where relationships required the teacher facilitating student-led change, or improved resourcing in terms of practical materials. Not surprisingly, the most positive feedback occurred from the teachers where strong support from senior leadership provided the necessary planning time and resourcing. When this happened, teachers found the inter-departmental collaboration highly stimulating and productive. Where teachers struggled with the STEAM inquiry, they cited insufficient curriculum and planning time, insecurity over content and pedagogy, and lack of lesson time to do justice to the inquiries. The following is a summary of what the teachers described as benefits to the work that has been accomplished:

- Facilitated the collaboration of STEAM teachers to the advantage of each of the separate subject curricula.
- Increased engagement of students and the development of STEAM competence.
- The promotion of solution-oriented active learning in the classrooms.
- The promotion of science and technology as possible careers.
- Increased collaboration of students working effectively together.
- Increased confidence and skills of students to collaborate effectively with people such as scientists and technologists.
- STEAM created opportunities for learners to take on social perspectives.

Conclusion

This was a small study involving only two classes from schools in different countries. Future research could investigate the effectiveness of this approach with more classes and across more year levels. However, this study has been particularly influential in terms of gaining the teacher confidence in experiencing new pedagogies. As with many pilot projects, it is often the most experienced and enthusiastic staff who participate, so the real challenge will emerge as STEAM programmes are more widely adopted across a year level. Further work is needed to establish exactly how the learning is more effective within the STEAM integration, but there is evidence that the STEAM approach is motivating teachers and students. In particular, the STEAM inquiry provided a pedagogic approach that uses development of generic skills such as collaboration and communication. Ideally, this approach could serve as a framework for STEAM teachers to develop their own projects on current themes in the future. This is challenging work, but judging by the teacher responses, STEAM as a curriculum integration has some affordances worth taking seriously by secondary schools and curriculum developers.

Acknowledgements

The project acknowledges the vital support of the teachers and students who have made this study possible. Thank you to the school leadership teams for their enthusiasm and vested interest that has allowed the study to continue to develop.

Dr Simon Taylor is a lecturer at the University of Waikato, and he teaches in the secondary initial teacher programme. His research interest lies in the areas of science education, student perspectives in secondary and tertiary environments, futurist learning, youth empowerment and education design. He is a keen advocate to encourage greater consultation with students in their learning, creating change in classroom culture, school culture and empowering both the worlds of the learner and teacher. https://www.waikato.ac.nz/staff-profiles/people/simont

Dr Paul Lowe is an accredited independent consultant with experience and a passion for team-based student-centred problem-based learning. His work is informed and driven by student and teacher voice. He has had leading roles in reform in science education in Abu Dhabi, New Zealand, Tokyo (all subjects) and China. His main PLD providers are: http://rteach/co.nz, http://core-ed.org.

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