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STEM education in the New Zealand setting: A case-study of STEM in a Year 7/8 classroom

Tanithe Hall

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STEM EDUCATION IN THE NEW ZEALAND SETTING: A CASE-STUDY OF STEM IN A YEAR 7/8 CLASSROOM

TANITHE HALL
New Zealand

Abstract

This article explains a case study undertaken for the purposes of answering the research questions: What does STEM education look like in a Year 7/8 New Zealand classroom? How do Year 7/8 students engage in the interdisciplinary approach of STEM education? Do/how do students value STEM learning in contrast to individual subject learning? This case study focused on a STEM unit of work with data collected through pre- and post-unit surveys, observations and student journals. Findings illustrate that students find STEM learning an engaging and interesting avenue for developing a deeper understanding when their learning is situated within a context they can connect with. The case study discussed in this article provides a rich example of STEM teaching and learning that will, hopefully, be informative for other teachers and researchers interested in exploring the integration of STEM education in the New Zealand setting.

Keywords

STEM education; case study; engagement; integration; interdisciplinary

Introduction

This paper describes a research project that sought to determine the impact of a STEM unit on Year 7/8 student engagement in learning. I was motivated to conduct the research because I had struggled to engage with the individual disciplines of science, technology and mathematics throughout my schooling, and I had seen the same struggle in many of my students. My reading had suggested that an integrated STEM education approach would help me contextualise these disciplines and make them more interesting and engaging for my students. I wanted to explore whether the approach was as engaging and valuable as I hypothesised it could be. I was also interested in if and how I could teach STEM within the framework of the New Zealand Curriculum (Ministry of Education, 2007). I chose to teach an adaptation of a readily available unit, as this was the first time I had taught STEM and I anticipated that the guidance it provided would support me in optimising my teaching and student STEM learning. I selected bushfires as the topic, as the Nelson area recently had bushfires which featured strongly in the local news, and I believed this would provide a relevant context for the students. I chose to work with Year 7/8 students, as I felt they would be able to navigate the different learning approaches of STEM education, and half of the particular class had done work around STEM education in the year prior to this study. I collected data from my class through observation, pre- and post-unit surveys and student journals. My findings support the idea that STEM education can be a way of increasing student engagement and motivation in their learning.

What is STEM education?

Many of the significant societal and environmental problems facing the world today require the use and integration of knowledge, understandings and practices from the STEM disciplines of science, technology, engineering and mathematics, making it an important focus for curriculum. STEM education, while it has a number of definitions (Bybee, 2013; English, 2016), has also been shown to have a positive impact on student interest and achievement (Mohd Shahali et al., 2016; Vennix et al., 2018). For the purposes of my study, I adopted an interdisciplinary approach focused on the integration of the four disciplines. That is, I viewed the disciplines as interlinked and interrelated learning areas (Granshaw, 2016), which allowed me to use their innate linkages to support student learning in a real-world context. This said, it is recognised that it can be challenging for teachers to plan and implement integrated STEM units which rely on their knowledge of each of the four STEM disciplines and their

Corresponding author
Tanithe Hall Tanithe@live.com
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capacity to integrate this (Banilower et al., 2018). There are also challenges in identifying contexts that are likely to be of interest to students, age appropriate and from which STEM ideas can be developed (Bybee, 2013; Sevian et al., 2018). Despite these known challenges, teachers often have limited opportunities for STEM-related professional development (English, 2016), which has been my experience. On the other hand, government agencies and other organisations have produced a range of curriculum materials that can be accessed online. These materials can be used without modification, or teachers can adapt them to a greater or lesser extent (Brown 2009; Remillard 2005). These resources are a great stepping stone for teachers seeking a foundation upon which to build their STEM teaching.

STEM education in New Zealand

Relatively speaking, the inclusion of STEM education as a learning approach in New Zealand schooling is a recent initiative. The current *New Zealand Curriculum* [NZC] (Ministry of Education, 2007) does not include specific mention of engineering or STEM. However, ideas and practices associated with engineering can be seen as falling within the umbrella of Technology Education as this is defined in the NZC (Granshaw, 2016). Within the 2017 revision, technology education is conceptualised as encompassing five technological areas: computational thinking, designing and developing digital outcomes, designing and developing material outcomes, designing and developing processed outcomes, and design and visual communication (Ministry of Education, 2018). Ideas relevant to STEM education can be found in various parts of the 2007 NZC document, with these including a focus on inquiry, being future-focused and involving the community. These aspects are described as part of STEM education on the Ministry of Education's Te Kete Ipurangi (TKI) website (Ministry of Education, n.d.b), which describes STEM education as being inquiry-based, authentic, focused on real-world problems and future focused.

The research design and focus: The bushfire unit

My research project was an interpretative case study. It was framed by the following questions:

- What does STEM education look like in a Year 7/8 New Zealand classroom?
- How do Year 7/8 students engage in the interdisciplinary approach of STEM education?
- Do/how do students value STEM learning in contrast to individual subject learning?

My research was undertaken in a decile 10 South Auckland school in a custom-built innovative learning environment. I worked with a Year 7 and 8 class of 32 students and their teacher. The students came from a range of cultural and socioeconomic backgrounds. Ethical approval was gained for the study and 25 students gave their informed consent to participate. The other seven students participated in the bushfire unit but no data was collected from them. I collected data in the form of pre- and post-unit surveys, student learning journals and observations. Photographs and video evidence of students' learning was collected along with audio recordings of student presentations.

For the study I trialled the bushfire unit that had been written by the Western Australia Department of Education (Department of Education, n.d) to fit with their curriculum. I chose this unit because I expected my students might have some interest in, and prior knowledge of, bushfires due to the recent Nelson bushfire that had received nationwide media coverage. The unit documentation provided many resources and links to resources to support the teaching; however, the data and videos it included were based on Australian data and previous bushfires within Australia. I continued to use the Australian data provided on predictors of bushfires but replaced the videos and based class discussions on the Nelson bushfire of February 2019. The reason for using the Nelson bushfire videos was to ensure relevance to New Zealand students, a key aspect of STEM education. The overall unit task was to create a bushfire warning system.

I read through the unit achievement objectives and related these to achievement objectives within the NZC. I identified and used objectives from Level 3 of the NZC to help ensure the unit was accessible to all the students in my class. From the science curriculum, the objectives focused on the development of science understanding of the weather and other environmental factors that create the conditions under which bushfires occur and the development of students' understanding of the impact of bushfires on living things, infrastructure and communities. Within digital technologies, the objectives were around computational thinking and students developing, representing and communicating an algorithm to an audience. The use of computational thinking to support the learning of algorithms falls under mathematics within the Western Australian Curriculum (Department of Education, n.d), but in New Zealand it is located in the Digital Technologies Curriculum (Ministry of Education, n.d.a). Within the mathematics curriculum, students were required to use probability and statistical literacy to analyse tabular displays of Australian Bureau of Meteorology (BoM) data, complete calculations and engage in pre-algebraic thinking to run and test their algorithms against real-world data.

Results

Student pre-survey

Data from the bushfire pre-unit survey showed that 77 percent (n=22) of students rated the usefulness of mathematics and technology in their future at an 8 or above out of 10, with 63 percent of students rating science at 8 or above. Most students (81%) believed that the skills learned through STEM education would be useful to them in the future.

The teaching sequence

In the first lesson, students were introduced to the unit and given the opportunity to share their prior knowledge about bushfires through a collaborative Padlet. This activity showed that students had a good understanding of what a bushfire is and where they are likely to occur. It is also evident from the comments that students had some understanding of the causes of bushfires and the damage they can cause to the environment. On the Padlet, students suggested that bushfires can be caused by dry grass and trees, fireworks, and small fires that haven't been looked after. A common trend, however, in all of the comments on the Padlet, was that all students believed that bushfires happened in remote bushland areas away from suburbia and were not something that could happen in areas near them.

Following this activity, the students watched videos from YouTube about the 2019 Nelson bushfire and discussed in small groups what they knew about this event and any feelings or experiences they had in relation to it. From my observations, more than half of the students were surprised by the devastation caused by the fire and how difficult it is to extinguish these types of fires. While watching the videos, students made statements such as, "That is so, so sad" (Student 22) and, "Wow look at all of the burnt ground" (Student 5). Students were then split into four groups to complete a bus stop activity. The questions used for this activity were designed by the Western Australia Department of Education (Department of Education, n.d) to further probe student prior knowledge about bushfires. Students then returned to the whole class setting to look over their shared ideas, with the standout ideas being added to a Padlet. The information provided by the students on the bus stop activity indicated that after watching the bushfire videos they were now taking a more personal approach to their answers. Student comments included: "The impact on our community would be huge", "It might change their mindset. Small children could suffer trauma from the experience", and "We need to be careful when we are using fireworks or having campfires."

The focus of the second lesson was on algorithms. I introduced the lesson by discussing previous occasions where the students had completed algorithms and prompted students to recall times they had used or created algorithms in class in the past. Students were all able to identify a previous instance they had worked with algorithms. Students then worked through the 'red shoes' flowchart (see Figure 1) from the bushfire unit. With my guidance, the students discussed the different variables within the chart, such as finding shoes and finding the right colour of shoe. Small group discussions took place around how to alter the flow chart to include the new variables indicated within the unit, such as a maximum price limit or shoe size, and how these new variables could affect the chart as a whole. Students considered where in the flow chart it was best to include these new variables to provide the right effect and where the flow chart would take them based on their answers.

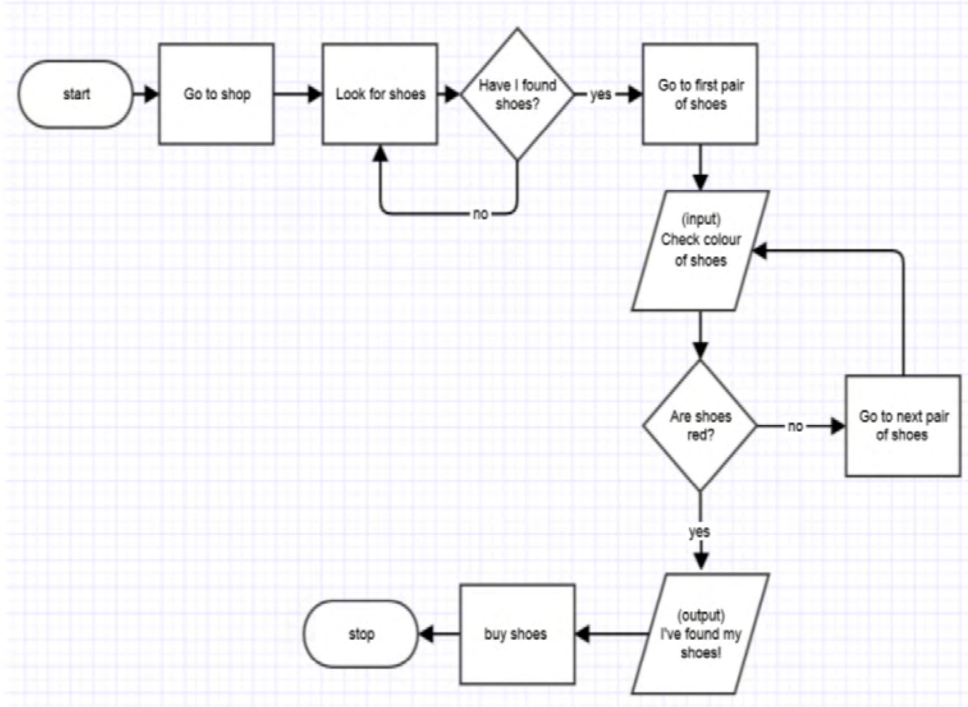

Figure 1: Red shoes flowchart.

The following is an example of the discussion that took place between the members of one group and me. It illustrates that students were able to think critically about the algorithm and its real-world application to ensure the placement of variables made sense.

> Teacher: Where in the chart do you think we need to put the price variable? Is it going to be before going to the shop?
>
> Student 17: No of course not.
>
> Teacher: Well, why not?
>
> Student 17: Because you need to be at the shop looking at shoes and then you think about the price.
>
> Teacher: Okay so then where do you think we need to start thinking about the price if we are shoe shopping?
>
> Student 5: Probably like once you've found red shoes because you know you want red shoes so may as well just look at the price of them.
>
> Teacher: Great thinking. So we've found red shoes but they are too expensive, where do we go from here? Right back to the start?
>
> Student 17: No, we just go back to the looking for another red pair of shoes. No point leaving the shop just because that one pair of shoes is too expensive.
>
> Teacher: It's great to see you are thinking about what you would do if you were actually in the shop following this algorithm.

Time was then spent sharing with students the different types of flowchart symbols and their meanings. The discussion reassured me that the students had a sound grasp of algorithms at this point. We then moved on to applying algorithms to the problem of producing a bush fire warning system.

As a first step to addressing this problem, the class reviewed the terminology used to analyse weather and fire risk, such as temperature, humidity and wind speed. The inputs and outputs needed for a bushfire warning system were discussed as a whole class, with students being given the opportunity to share their ideas with each other. Students were able to identify that high temperatures were necessary for a bushfire to occur and they related this to the ground and trees being dry. Most students struggled with the notion of humidity, and so I prompted them to look it up on their devices and share this information with their peers. Some of the students from non-English speaking backgrounds had further questions about humidity, at which point I gathered the students who still didn't understand together and explained humidity to them. I helped them build an understanding based on their own experiences of 'feeling' humidity, such as sticky skin. This was an opportunity for us to discuss the science in the unit by looking at humidity being the amount of water vapour in the air.

The students were divided in their understanding of wind speed and its impact on bushfires, as well as the impact humidity would have. This may have been due to their preconceived ideas of what the impact would be on a fire as evidenced by comments such as, "Well if the wind is going fast surely it would just blow the fire out" (Student 9) and, "If the humidity is high and everything is getting sticky then it might make it easier for the fire to stick to it and go up" (Student 5). Finally, the students were given bushfire risk data from the Western Australian Department of Education's Bushfire Warning unit (Department of Education, n.d) and organised themselves into groups of four to work on an algorithm for determining bushfire risk. The image below is an example of the final product of one group's work during this part of the lesson.

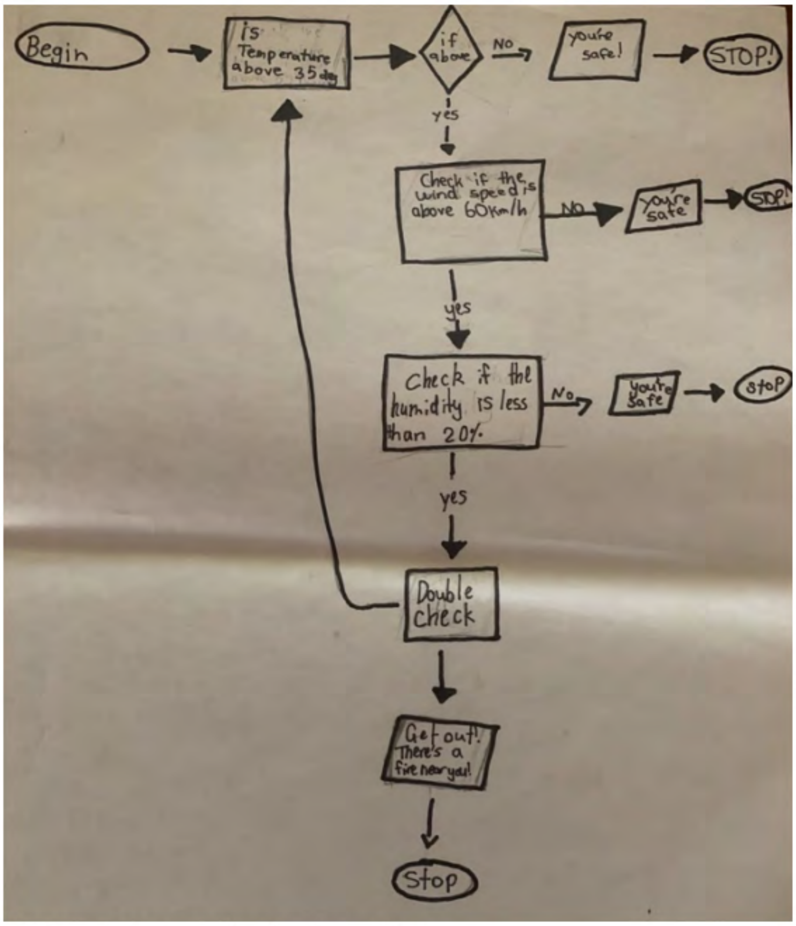

Figure 2: Group one's algorithm.

Lesson three began with the class watching a video describing the science behind how wind speed, temperature and humidity work together to influence the chance of a bushfire occurring. The purpose in showing this video was to help build the students' understanding of how each of the factors they had used in their algorithms from lesson two worked together to create a heightened bushfire risk. Following this, the students were put into teacher-directed groupings and given another chance to create an algorithm to determine bushfire risk. I grouped the students to ensure that there was a range of understanding in each group. Each group was again provided with the Bureau of Meteorology bushfire information from the Bushfire Warning unit (Department of Education, n.d) related to bushfires in

Australia. This information was used because similar information was unavailable for the Nelson bushfires, and this data was essential for consolidating the students' learning. Students used this information to identify two low-risk and two high-risk days using what they had learned about the contributing factors for bushfires. During a whole-class discussion, students noted that they found it quite easy to find the two high-risk days, given that the information focused on times where bushfires had occurred. A representative comment was: "Finding the high-risk days was easy because there was a high temperature, a low humidity and a high wind speed but the low days were hard because there were only two of them in all of that information" (classroom observation). On the other hand, another student stated, "The low-risk days were confusing because one of the low-risk days was in the middle of a bushfire" (classroom observation). This contradiction of information opened up this group's mind to the fact that risk factors are not determinate to occurrence, meaning that just because the risk factors are low doesn't mean a bushfire can't happen. Each group then used this information to test the accuracy of the algorithms they created. If the algorithms did not produce the expected result, the teacher encouraged the students to debug their algorithms to identify where the error occurred and take steps to correct these errors.

After students had successfully debugged their own algorithms and tested them using the identified high and low risk days, they then switched their algorithm with another group's and tested that group's algorithm using the data provided. They did this the same way they tested their own algorithms, that is by using the temperature, wind speed and humidity recorded during Australian bushfires and working through their peer group's algorithm. In all cases, the algorithms functioned correctly through this challenge, even though the algorithms weren't completely foolproof due to some students' continued belief that it is necessary to have a high risk in all three factors in order to have a high risk of bushfire occurrence. This limitation in the students' understanding is evident in the example provided above (see Figure 2) where the algorithms don't go further once a negative answer to a question was provided.

During lesson four, students were given the opportunity to create a presentation of their algorithm. For the presentation, each group member was required to discuss a part of the thinking behind the algorithm, how the group decided to create it, what each aspect represents and how well the testing and debugging process went. The groups all did their presentation using a slideshow with images of their algorithms. They talked through the algorithm and what would happen at each stage of the process.

On the basis of the presentations, it was evident that the students had developed an understanding of bushfire dangers and the factors that influence risk levels despite fluctuating engagement levels dependent on the content of each lesson. Each member of every group took part in their group's presentation through the development of a script. Even students who were generally being fairly shy and usually chose not to participate in activities that required them to speak to a group or class, actively participated in this activity. This can be seen as evidence of good collaboration within the groups that led to each group member feeling comfortable and confident to share. It provides an example of how STEM education can encourage participation from all students, as was a suggested outcome.

In the final stage of this unit, students were given the opportunity to create a bushfire warning system based on their algorithm and the knowledge they had gained. Students were able to do this using either physical materials or digital technologies. One of the groups that chose to use physical materials completed a board game that focused primarily on the new terminology learned during the unit, such as wind speed, temperature and humidity, and how these factor into the risk level of a bushfire. Parts of the game did not relate to the learning that had taken place, such as discussing household appliances or movies but, on the whole, the game demonstrated that the students understood the concepts taught during this unit and that they were able to apply them to a different kind of output. Below are photos of the board game and the pieces the students made to play the game. The game requires players to roll a dice and move their 'water canister' the number of spaces shown. The squares stated things such as, 'Stay put the temp is 18C', and, 'The wind speed is 51 km/h. Get out! Move forward four spaces'. These squares show the students' understanding of the risk factors involved in bushfires. The cards that players picked up when they landed on a 'pick up card' square made similar statements about wind speed, humidity and temperature, all of which were factors that determined whether a player needed to 'get out' as the result of a high risk and therefore move forward or back a set number of spaces, or stay where they are in the case of low-risk results.

Figure 3: Bushfire board game.

The group that completed the digital version of the bushfire warning system did so using Scratch Software (https://scratch.mit.edu/). This group entitled their system 'Horsey on Fire'. Their system worked by inputting the data needed to determine bushfire risks, such as temperature, humidity and wind speed. The programme would then provide the risk level for a bushfire occurring in the form of the horse's habitat becoming engulfed in flame (high risk), or the horse happily moving about on the screen (low risk). The programme also suggested what action should be taken, such as staying put or getting out. The students then made a video detailing how they made their app and how their system worked. This showed the student understood the computational thinking skills that are part of the digital technologies curriculum. It also showed that students understood that the variable inputs (temperature, humidity and wind speed) had an effect on the output (bushfire or no bushfire) as was displayed through the movement of the horse through either a screen with fire, or a screen without.

In the post-unit survey, mathematics usefulness was rated at 8 out of 10 or above by 81 percent of the students, an increase of four percent. Technology's rating for usefulness by the students with a rating of 8 out of 10 or above rose by 9 to 86 percent in the post-unit survey, and the science rating of 8 out of 10 or above increased by 18 percent to 81 percent of students in the post-unit survey. The usefulness of STEM education skills with a rating of 8 out of 10 or above, however, decreased by 18 to only 63 percent of the students' feeling that these skills will be useful to their futures. Although the overall percentage of students who provided an 8 out of 10 or above for understanding of STEM education remained the same at 72 percent, there were five students who provided a slightly lower score in their post-unit survey than they had in their pre-unit survey.

Summary of outcomes and insights

Student outcomes: The use of the pre- and post- unit surveys provided me with insight into the students' thinking with regard to their learning within the individual STEM disciplines and how this changed when these disciplines were taught using the integrated interdisciplinary approach of STEM education. The unit was designed to increase students' understanding of STEM. However, the post-unit surveys showed that some students had become less certain of what STEM education was. Although an unexpected response, this could be due to their experience prompting these students to question their preconceived ideas of STEM, as they had predominantly used digital technologies to complete units they considered to be STEM previously. The observations supported the notion that STEM education increases student engagement in the STEM disciplines and student enjoyment in learning in these areas. Findings also support the concept that inquiry-based approaches can facilitate students' understanding of the information being taught and develop their information literacy in a manner similar to that identified by Chu et al. (2011) and Abdi (2014).

Insights into STEM teaching and learning: There is an abundance of STEM education units available online and my experience illustrates that they can be used successfully albeit with some adaptation. Drake and Sherin (2009) propose that overtime teachers can develop a 'curriculum vision' as they learn from, and about, using a set of curriculum materials. In my case I learned that STEM education can provide an avenue for more students to participate and have success in learning, that STEM education can provide opportunities for genuine collaboration and that, as a teacher, it is possible to feel confident teaching in an area I was not previously confident teaching in using a prepared unit. More specifically, I reinforced that it is important to know your students so that you can identify units that will be appealing and appropriate for them. In this instance, I expected the Bushfire unit would be of interest to my students because of the Nelson bushfires; however, I am not sure it was for some of them. This experience suggests that teachers cannot assume a topical event will be viewed as interesting by students and that it would be worthwhile surveying students to ascertain if they found it interesting and to find ways to make it interesting beyond the unit itself. This experience also reinforced that it is important to understand the students' prior knowledge before launching a unit. With this unit, I didn't fully realise students may not have prior knowledge around the concepts of weather, such as humidity, temperature and wind speed. I hadn't fully appreciated the implications of the unit provided survey of prior knowledge focusing more on bushfires than content knowledge relevant to understanding them.

Past research has shown that teachers' use of curriculum materials is influenced by their knowledge, features of the curriculum materials and teachers' professional context (Choppin et al., 2018; Moore et al., 2021). The bushfire unit included detail on unit activities and ideas I was confident with, including my understanding of algorithms and computational thinking. The unit included a variety of activities which involved students working in different groupings. Students were familiar with these which ensured that they were able to complete the work collaboratively and in a timely manner as was intended. I used digital technologies to share videos and meteorological data, for the students to complete their self-reflection journals, and to save and store photographs of students working and their final products. Students used digital technologies to research bushfire warning systems. They were given the option to use digital technologies to complete their summative task of creating a bushfire warning system. Students responded positively to this choice but it is interesting to note that one group produced a board game. Their responses also indicated that students appreciated the chance to share their learning with their peers.

I set out to find out what STEM learning might look like and if students would find it engaging. This paper has aimed to illustrate what it can look like, although not all students reported a more positive view of STEM subjects. I also confirmed that online STEM units can be used, albeit after adaptation. As with all things classroom based, there is no one-size-fits-all approach to the implementation of STEM education.

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